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NBS SPECIAL PUBLICATION 346

Hydraulic Research in the United States, 1970

**Including Contributions
From Canadian Laboratories**

**U.S.
DEPARTMENT
OF
COMMERCE**

**National
Bureau
of
Standards**

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NO. 346
1971

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¹ Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

² Part of the Center for Radiation Research.

³ Located at Boulder, Colorado 80302.

Hydraulic Research in the United States 1970

Including Contributions from Canadian Laboratories

Edited by Gershon Kulin and Pauline H. Gurewitz



National Bureau of Standards Special Publication 346

Nat. Bur. Stand. (U.S.), Spec. Publ. 346, 354 pages (Mar. 1971)

CODEN: XNBSA

Issued March 1971

ABSTRACT

Current and recently concluded research projects in hydraulics and hydrodynamics for the years 1969-1970 are summarized. Projects from more than 250 university, industrial, state and federal government laboratories in the United States and Canada are reported.

Key words: Fluid mechanics; hydraulic engineering; hydraulic research; hydraulics; hydrodynamics; model studies; research summaries.

Library of Congress Catalog Card Number: 34-3323

PREFACE

"Hydraulic Research in the United States" first appeared in 1933 in answer to a need for a publication devoted to keeping hydraulicians aware of pertinent current activity in research laboratories throughout the United States and Canada. With the exception of a few World War II years, it was published annually through 1966, after which publication became biennial.

The National Bureau of Standards appreciates the cooperation of the more than 250 organizations which have contributed to this issue their summaries of hydraulic and hydrologic research and of other fluid mechanics research of interest and usefulness to hydraulicians. These reporting organizations are listed beginning on page v. Although efforts are made to solicit reports from all laboratories whose work comes to our attention, the National Bureau of Standards cannot assume responsibility for the completeness of this publication. We must depend in the last analysis upon reporting laboratories for the completeness of the coverage of their own programs, and upon new laboratories engaged in pertinent research to bring their activities to our attention.

Detailed information regarding the research projects reported here should be obtained from the correspondent listed under (c) or immediately following the title and address of the organization reporting the work. The National Bureau of Standards does not maintain a file of publications, reports or other detailed information on research projects reported by other laboratories. It is of course understood that laboratories submitting reports on their work will be willing to supply additional information to properly qualified inquirers.

Users of "Hydraulic Research in the United States" are also referred to the "Water Resources Research Catalog," prepared by the Science Information Exchange of the Smithsonian Institution for the Office of Water Resources Research, U.S. Department of the Interior. Volume 5 is now available, and information on this and earlier issues may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (See also "Key to Projects" on next page.)

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KEY TO PROJECTS

- (a) Number and title of project
Project numbers, once assigned, are repeated in each issue for identification purposes until the project is completed. In this issue the numbers (6884) and above refer to projects being reported for the first time. Numbers followed by W, e.g. (001W), refer to projects included here by title only, but which are completely summarized in "Water Resources Research Catalog." (See "Preface.")
- (b) Project conducted for
Only out-of-house sponsors are listed here. Absence of an entry indicates in-house support. (See also "Supporting Agency Index," page 344.)
- (c) Correspondent
Where there is no entry here, refer to the correspondent cited directly following the title and address of the reporting laboratory. (See also "Preface.")
- (d) Nature of Project
Basic or applied; theoretical, experimental; thesis, etc.
- (e) Description of Project
- (f) Present status
Absence of an entry here implies that the project was in an active status at time of submission.
- (g) Results
In many continuing projects this section contains only results since the previous issue of "Hydraulic Research in the United States." For completeness, readers are encouraged to consult earlier issues and/or publications listed under (h).
- (h) Publications
For the continuing projects, only publications since the last issue are generally listed. Older publications are listed when there have been no new publications since the last issue or when a project is being reported for the first time.

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PROJECT REPORTS FROM UNIVERSITY, STATE AND INDUSTRIAL LABORATORIES

AEROJET LIQUID ROCKET COMPANY, P. O. Box 13222, Sacramento, California 95813. Dr. D. E. Robison, Vice President, Engineering Operations.

(7279)

DEVELOPMENT OF STEADY-STATE AND DYNAMIC PERFORMANCE PREDICTION METHODS FOR TURBOPUMP SELF COMPENSATING THRUST BALANCE SYSTEMS.

(b) National Aeronautics and Space Administration.

(c) P. S. Buckmann or L. Luehr.

(d) Analytical and experimental; applied and development.

(e) The objective of the "Thrust Balance Stability" program was to formulate and experimentally verify a computerized mathematical logic to predict steady state and dynamic characteristics of selected turbomachinery axial thrust balance systems. Compressible and incompressible flow for series and parallel flow systems were considered.

(f) Completed.

(g) Theoretical correlation with experimental data was in good agreement providing design confidence for high pressure thrust balancing systems.

AEROTHERM CORPORATION, 485 Clyde Avenue, Mountain View, California 94040. Dr. A. H. Nayfeh.

(7128)

FINITE AMPLITUDE SURFACE WAVES

(d) Theoretical; basic research.

(e) Investigation of the interaction of gravity and capillary waves.

(f) Completed.

(h) "Finite Amplitude Surface Waves," A. H. Nayfeh, J. Fluid Mech., Vol. 40, pp. 671-684 (1970).

"Triple- and Quintuple-Dimpled Wave Profiles in Deep Water," A. H. Nayfeh, Physics of Fluids, Vol. 13, 3, March 1970, pp. 545-550.

(7129)

NONLINEAR STABILITY OF LIQUID FILMS.

(d) Theoretical; basic research.

(e) Investigation of the stability of a liquid film under the influence of a gravitational field with respect to finite amplitude disturbances.

(f) Completed.

(g) "On the Nonlinear Lamb-Taylor Instability," A. H. Nayfeh, J. Fluid Mech., Vol. 38, Part 3, pp. 619-631 (1969).

"Nonlinear Stability of a Liquid Jet," A. H. Nayfeh, Physics of Fluids, Vol. 13, 4, April 1970, pp. 841-847.

(7130)

EFFECT OF ANGLE-OF-ATTACK OSCILLATION ON THE STABILITY OF LIQUID FILMS.

(d) Theoretical; basic research.

(e) To assess the effect of the oscillatory component of the deceleration force on the stability of a liquid film at the stagnation region of a reentry body.

(f) Completed.

(g) A. H. Nayfeh, AIAA J., Vol. 7, No. 10, pp. 2026-2028 (1969).

(7131)

STABILITY OF A LIQUID FILM OVER A ROTATING CYLINDER.

(d) Theoretical; basic research.

(e) Investigation of the effect of centrifugal forces due to spinning on the stability of a liquid layer on a spinning body.

(f) Completed.

(g) A. H. Nayfeh, AIAA J., Vol. 7, No. 9, pp. 1812-1813. (1969).

UNIVERSITY OF ALABAMA IN HUNTSVILLE, Division of Engineering, P. O. Box 1247, Huntsville, Alabama 35807. Dr. Wilhelm K. Kubitzka, Division Director.

(6081)

DRAG ON TWO-DIMENSIONAL PLATES IN AN INCOMPRESSIBLE OSCILLATING FLOW AT LOW REYNOLDS NUMBERS.

(c) Professor C. C. Shih.

(d) Experimental; applied research; M. S. thesis completed.

(e) Drag forces are to be determined for a flat plate oscillating normal to its plane. This study is to provide data for constructing a damping law for antislosh baffles under low Reynolds number conditions. Such an expression for damping could be used to predict the damping of baffles in the tanks of an orbiting vehicle.

(6082)

THE EFFECTS OF UNSTEADY FLOW UPON THE PRESSURE DISTRIBUTION AROUND SUBMERGED BODIES.

(c) Professor C. C. Shih.

(d) Experimental; applied research; thesis, continued.

(e) Pressure distribution time histories will be measured in a uniformly accelerated incompressible flow that is started impulsively. The object of this experiment is to provide data for vehicle design and for comparison with current theories and numerical experiments. In this area experimental data are sparse or nonexistent. Also measurements of drag and lift forces are being made.

UNIVERSITY OF ALASKA, Institute of Water Resources, College, Alaska 99701. Dr. Robert F. Carlson, Associate Professor.

(7815)

WATER QUALITY MODEL OF COOK INLET.

(b) Office of Water Resources Research.

(d) Theoretical; field; applied research.

(e) A computer model has been developed to investigate the movement of the waste discharge in Knik Arm, Cook Inlet, Alaska.

(g) A one-dimensional numerical model of the water flow has been developed. The water quality model is in progress.

ALLIS-CHAILMERS HYDRAULIC LABORATORY, Hydro Turbine-Generator Division, P. O. Box 712, York, Pennsylvania 17405. Warren G. Whippen, Manager, Product Development.

(7132)

CENTRIFUGAL STRESSES IN A PUMP/TURBINE RUNNER.

- (c) John S. Gray, Jr., Engr., Product Development Department.
- (d) Experimental; applied research.
- (e) Find maximum stresses in a pump/turbine runner due to centrifugal forces at runaway speeds, and compare these results with those obtained by our Finite Element Program.

(7133)

SURFACE FINISH AND SCALE EFFECTS.

- (c) John Martin, Senior Engineer I.
- (d) Theoretical; experimental; applied research.
- (e) Abundant information exists on the effect of surface roughness on the coefficient of friction in pipes, on plates and on rotating disks. The object of the present research is to establish the relation between the classic "sand roughness" used in the published literature and the equivalent roughness generated by various industrial processes of fabrication and machining used in the hydraulic turbine industry.

(7134)

DRAFT TUBE SURGE AND ROTATING STALL PHENOMENA.

- (c) John Martin, Senior Engineer I.
- (d) Experimental, correlated with field observation.
- (e) Dynamic pressure in the draft tube and the wicket gate passage way is recorded during steady state operation of a model of turbine or pump/turbine. The object of the study is the correlation of the amplitudes and frequency readings with parameters pertaining to the design and performance of the machine, as well as to the system in which the machine operates.
- (h) "Power Swings in Hydroelectric Power Plants," W. J. Rheingans, ASME Trans., April, 1940.

(7135)

RESISTANCE TO CAVITATION IN CORROSIVE WATER.

- (c) John Martin, Senior Engineer I.
- (d) Experimental; applied research.
- (e) A 20-kHz piezoelectric transducer is used to vibrate a metal specimen in different waters. The amplitude of vibration, hence the rate of damage, is controllable. The object of the study is to establish the part played by corrosion intensity, as well as different chemical compositions of natural water such as those commonly found in lakes and rivers.

(7136)

INFLUENCE OF BOUNDARY CONDITIONS ON THE STABILITY AND DISCHARGE OF SUBMERGED HOWELL-BUNGER VALVES.

- (c) Jack Fisch and John Martin.
- (d) Experimental; field investigation.
- (e) Several influences of the discharge coefficient and the stability of the flow have been investigated: the submergence (coefficient Δ), the design of the discharge chamber and of elements immediately upstream of the valve.
- (f) Completed.
- (h) "Solution of Vibration Problems Experienced with Howell-Bunger Valves at Round Butte Dam," Donald J. Broehl and J. Fisch, Commission Internationale des Grands Barrages, Neuvieme Congres, Istanbul, 1967, Paper Q.33 R.20.

(7137)

INTAKE FOR AXIAL FLOW PUMP.

- (c) Ignacy Swiecicki, Dev. Engr., Product Development Department.
- (d) Experimental; of an applied research nature.
- (e) Two blade 130-inch axial flow pumps in fishway facilities experienced shaft failures due to the uneven loading of the impeller blades. Model tests in air revealed two distinctly different flow patterns in the intake; each, once set by a temporary outside disturbance, was remaining steady. One was associated with a right hand swirl in the intake, and the second with a left hand swirl. Several modifications of the intake were tested and the geometry of the intake established giving satisfactory impeller blade loading.
- (f) Completed.

(7138)

INVESTIGATION OF TIP CAVITATION EFFECTS ON AXIAL-FLOW TURBINE MODELS.

- (d) Applied, development, allied with field investigation.
- (e) This program relates cavitation formation and damage in the field to the model and examines the relationship of tip vortex generation to blade clearance and geometry. The effects of skirt configurations are included.
- (g) Boundary layer phenomena and scale effects obscure exact similitude but an optimum skirt design is suggested.

(7139)

INVESTIGATION INTO THE THERMODYNAMIC METHOD OF EFFICIENCY TESTING FOR HYDRAULIC TURBINES AND PUMPS.

- (c) Laurence F. Henry, Project Engr.
- (d) Field investigation; operation.
- (e) Project entails laboratory and field use of existing commercial instrumentation for the purpose of evaluating the "thermodynamic method" for testing hydraulic turbines and pumps. The method has been accepted by the International Electrotechnical Commission for the efficiency testing of large hydraulic machines but not much work has been done with the method in the U.S. Practical experience with the method and various instrumentation is being sought.

(7140)

FUNDAMENTAL RESEARCH INTO THE CAUSES OF SEVERE AND UNANTICIPATED DAMAGE TO A PUMP/TURBINE UNIT.

- (b) Joint project with MIT Mechanical Engrg. Dept.
- (c) W. L. Swift, Engr., Product Development Dept.
- (d) Experimental, theoretical and field investigations are involved. Classified as basic and applied research, development. At least one Master's thesis will result.
- (e) As a result of a recent accident with a large reversible pump/turbine, the following major areas of study are involved in an investigation to establish in detail the cause(s) of the accident and measures to prevent similar occurrences: fatigue and fracture studies of components; water passage dynamic response characteristics; wicket gate dynamic loads and flutter characteristics; and broad-band simulations and verification of observed prototype behaviour.

ARIZONA STATE UNIVERSITY, Department of Mechanical Engineering, Tempe, Arizona 85281. Professor Warren Rice, Department Chairman.

(6051)

UNSTEADY LAMINAR FLOW FIELD ANALYSIS.

- (d) Analytical; applied research resulting in doctoral thesis.
- (e) Development of methods of solving unsteady laminar flow problem in complex conduits.
- (g) Solutions for the laminar flow of an incompressible fluid in a conduit of arbitrary cross section, from an arbitrary initial flow condition and with an arbitrary time-varying pressure gradient.
- (h) "Duhamel's Theorem for Two-Dimensional Unsteady Laminar Incompressible Fluid Flow Problems with Regular and Non-Regular Boundaries," Harry K. Hepworth, Ph.D. dissertation, Dept. of Mech. Engrg., Arizona State University, August 1969.

(7141)

LAMINAR FLOW BETWEEN CO-ROTATING DISKS.

- (d) Analytical and experimental; applied research resulting in doctoral thesis.
- (e) Development of solutions for flow useful in development and design of multiple-disk turbomachinery.
- (g) Analytical; computerized solutions for the velocity and pressure fields for the flow of hydraulic fluids between rotating disks, with experimental verification of analytical results.
- (h) "An Integral Solution for the Three-Dimensional, Laminar Flow of a Viscous, Incompressible Fluid Between Parallel, Co-Rotating Disks," Brent E. Boyack, Ph.D. dissertation, Dept. of Mechanical Engrg., Arizona State University, May 1969.
"An Experimental Investigation of the Inward Flow of an Incompressible Viscous Fluid Between Parallel Co-Rotating Disks," Robert G. Adams, Ph.D. dissertation, Dept. of Mechanical Engineering, Arizona State University, May 1969.

(7142)

LAMINAR FLOW BETWEEN ROTATING SURFACES OF REVOLUTION.

- (d) Analytical; basic and applied research for doctoral thesis.
- (e) Development of solutions for the velocity and pressure fields for flow of a hydraulic fluid between surfaces of revolution that are rotating or stationary.
- (g) Similarity solutions for several families of surface shapes, both rotating and stationary, with computer programs for solving the similarity problems.
- (h) "On Possible Similarity Solutions for the Laminar Flow of a Viscous, Incompressible Fluid Between Rotating Coaxial Surfaces of Revolution," Kenneth W. McAlister, Ph.D. dissertation, Department of Engineering Mechanics, Arizona State University, February 1970.

BATTELLE MEMORIAL INSTITUTE, Pacific Northwest Laboratory, P. O. Box 999, Richland, Washington 99352. W. A. Haney, Research Program Coordinator, Water and Land Resources Department.

For summaries of the following projects, refer to Water Resources Research Catalog, Volume 4:

(076W)

SIMULATION MODELING OF THERMAL EFFECTS ON SELECTED RIVER SYSTEMS, 4.0270.

(077W)

A THREE-DIMENSIONAL STUDY OF PARAMETERS RELATED TO CURRENT DISTRIBUTION IN LAKE ROOSEVELT, 5.1245.

(078W)

COLUMBIA RIVER SEDIMENT STUDIES, 5.1249.

(079W)

TEMPERATURE PREDICTION STUDIES RELATING TO THE DEVELOPMENT OF A POWER REACTOR SITE ON THE LOWER COLUMBIA RIVER, 8.0303. (Completed in 1969.)

(7143)

MOVEMENT OF RADIONUCLIDES THROUGH SOILS.

- (b) USACE (Atlantic Richfield Hanford Company).
- (c) M. H. Karr, Manager, Earth Sciences Section.
- (d) Experimental and field investigation; applied research.
- (e) To develop accurate and applicable transport models for describing the movement of radionuclides (and other pollutants) in complex saturated groundwater systems. Both soil chemistry (not discussed here) and hydrology research are included in the program. The latter includes the formulation of algorithms and computer programs for numerical solution of system transmissibility distribution using groundwater potentials and pump test data. The programs are to be capable of analyzing both transient and steady state groundwater systems in significant detail.
- (g) Algorithms and computer routines have been developed and applied for solving variable aquifer thickness, transient flow problems (VTT model) and for partially-saturated, transient flow problems (PST model). Graphical display system was developed, utilizing a CRT memory scope in conjunction with the digital computer, to provide visual presentation of results. Also the system was made man-machine interactive by incorporating some analog controls with the digital computer.
- (h) "Groundwater Flow Simulated on Computer Aids Nuclear Plant Radioactive Waste Study," R. T. Jaske, Industrial Water Engrg., Vol. 6, No. 12, pp. 48-49, December 1969.

POLYTECHNIC INSTITUTE OF BROOKLYN, Department of Aerospace Engineering and Applied Mechanics, Rte. 110, Farmingdale, N. Y. 11735. Dr. Joseph Kempner, Department Head.

(7153)

VISCOUS FLOW ALONG A CORNER.

- (g) Solutions for the viscous incompressible flow along a right angle corner have been found by a method of successive iteration.
- (h) "Viscous Flow Along a Corner, Part I, Asymptotic Features of the Corner Layer Equations," A. Pal and S. G. Rubin, PIBAL Rep. 69-18, May 1969.
"Viscous Flow Along a Corner, Part II, Numerical Solution of Corner Layer Equations," S. G. Rubin and B. Grossman, PIBAL Rep. 69-33, Aug. 1969.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Division of Engineering and Applied Science, Engineering Science Department, Pasadena, California 91109. Dr. Francis H. Clauser, Division Chairman.

(1548)

PROBLEMS IN HYDRODYNAMICS

- (b) Office of Naval Research, Department of the Navy.
- (c) Professor Milton S. Plesset.
- (d) Theoretical and experimental; basic research.

- (e) Studies of cavitating and noncavitating flow; dynamic behavior of cavitation bubbles; theoretical studies of cavitation damage.
- (h) "A Physical Model of Liquid Helium," Din-Yu Hsieh Rep. No. 85-43, Calif. Inst. of Tech., Mar. 1968. "Ultrasonic Cavitation in Liquid Helium," Din-Yu Hsieh, Rep. No. 85-44, Calif. Inst. of Tech., March 1968.
- "Sublimation of a Monatomic Element," Ronald L. Kerber and Din-Yu Hsieh, Rep. No. 85-45.
- "Cavitating Flows," Milton S. Plesset, Rep. 85-46, Calif. Inst. of Tech., April 1969.
- "Tensile Strength of Liquids," Milton S. Plesset, Rep. 85-47, Calif. Inst. of Tech., April 1969.
- "Cavitation Erosion in Non-Aqueous Liquids," Milton S. Plesset, Rep. No. 85-48, Calif. Inst. of Tech., February 1970.
- "Tensile Strength of Liquids," Milton S. Plesset, in Cavitation State of Knowledge (ASME publication, 1969), pp. 15-26.
- "Cavitating Flows," Milton S. Plesset, in Topics in Ocean Engineering (Gulf Publishing Co., 1969).
- "Ultrasonic Cavitation in Liquid Helium," Din-Yu Hsieh. Presented at the 6th International Congress on Acoustics, Tokyo, Japan, Aug. 21-28, 1968.

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CALIFORNIA INSTITUTE OF TECHNOLOGY, Division of Engineering and Applied Science, W. M. Keck Laboratory of Hydraulics and Water Resources, Pasadena, California 91109. Dr. Francis H. Clauser, Division Chairman.

- (4075)
MECHANICS OF FLOW IN SAND-BED CHANNELS AT VERY LOW RATES OF SEDIMENT TRANSPORT.
- (b) National Science Foundation.
 - (c) Prof. V. A. Vanoni or Prof. N. H. Brooks.
 - (d) Experimental and theoretical research.
 - (e) Studies are made (1) of the development of dunes with time on a sand bed with flows which produce low rates of sediment transport and of the resulting changes in flow resistance as the dunes grow, (2) on the mechanism of entrainment of sediment by flowing water, and (3) of relations of geometric parameters of dunes and the frictional resistance to flow produced by the dunes with a view to predicting resistance from dune dimensions.
 - (f) Completed.
 - (h) Concluding discussion of "Relation Between Bed Forms and Friction in Streams," Vito A. Vanoni and Li-San Hwang, J. Hyd. Div., Proc., ASCE, Vol. 94, No. HY6, Nov. 1968, pp. 1524-1527.

- (4561)
DYNAMICS OF DENSITY-STRATIFIED WATER RESERVOIRS.
- (b) Federal Water Pollution Control Administration.
 - (c) Professor Norman H. Brooks.
 - (d) Basic theoretical and experimental research.
 - (e) (1) Further research on selective withdrawal currents has summarized the present state of knowledge, especially for application to large reservoirs.
 - (2) Reservoir mixing by pumping water from one level to another is being studied both by laboratory tank experiments and by computer simulation. The simulation technique predicts the response of the ambient density (or temperature) profile to the simultaneous effects of selective withdrawal from one layer, and discharge of the same fluid as a buoyant (or sinking) jet at a different level. The results will be useful in managing the quality of water in man-made lakes, in which

bottom waters often become oxygen deficient in summer due to the thermal stratification.

- (h) "Selective Withdrawal from Stratified Reservoirs," Norman H. Brooks and R. C. Y. Koh, Proc. ASCE, J. Hyd. Div., Vol. 95, HY4, July 1969, pp. 1369-1400.

- (5013)
DYNAMICS OF DENSITY-STRATIFIED GROUND-WATER FLOW.
- (b) Federal Water Pollution Control Administration.
 - (c) Professor Norman H. Brooks.
 - (d) Basic theoretical and experimental research.
 - (e) A theory was developed for the rate of growth of "finger" instabilities at an unstable diffusing interface in a stratified porous medium. This theoretical work was continued with Wooding's experimental investigations at C.S.I.R.O., Canberra, Australia, in the publication listed below. This theory is a contribution toward better basic understanding of convective overturning and mixing of hydrostatically unstable ground-water layers. Earlier work on selective withdrawal in density-stratified ground-water flow was published in 1968 (see below).
 - (f) Inactive.
 - (h) "A Two-Dimensional Sink in a Density-Stratified Porous Medium," E. John List, J. Fluid Mech., Vol. 33, Part 3, 2 Sept. 1968, pp. 529-543.
 - "Growth of Fingers at an Unstable Diffusing Interface in a Porous Medium or Hele-Shaw Cell," Robin A. Wooding, J. Fluid Mech., Vol. 39, Part 3, 1969, pp. 477-495.

- (5014)
WAVE-INDUCED OSCILLATIONS OF SMALL MOORED VESSELS.
- (b) Dept. of the Army, Corps of Engineers.
 - (c) Professor Fredric Raichlen or Mr. Jjin-jen Lee.
 - (d) Experimental and theoretical research.
 - (e) The objective of this research is to investigate the nature of wave-induced motions of small boats moored to fixed or floating docks. The study is directed toward understanding the problems of mooring small craft in harbors and providing information that will assist in planning. In this connection the investigation is divided into two phases: the dynamics of mooring and the response of harbors to incident wave systems. The problem of the response of harbors to waves is under investigation in a wave basin with wave generator and associated measuring and recording equipment. The basin is lined with wave absorbers and wave filters to simulate the condition of open-sea outside the harbor. Analytical and prototype studies are being conducted on the problem of the mooring of small boats, considering the mooring system to be an asymmetrical non-linear system.
 - (h) Discussion of "The Threshold of Surge Damage for Moored Ships," B. W. Wilson, Proc. Inst. of Civ. Engrs., 1967, 38 (Sept.), F. Raichlen, Inst. of Civ. Engrs., Vol. 40, July 1968, pp. 363-372.
 - "Wave Induced Oscillations in Harbors of Arbitrary Shape," W. M. Keck Lab. of Hyd. and Water Res., Calif. Inst. of Tech., Report KH-R-20, Dec. 1969, by Jjin-jen Lee. Also Ph.D. thesis by same title and author Dec. 1969, obtainable from University Microfilms, Inc., 313 No. 1st St., Ann Arbor, Mich.
- (5360)
MECHANICS OF SLUG FLOW IN STEEP CHANNELS.
- (b) Los Angeles County Flood Control District.
 - (c) Prof. Vito A. Vanoni; Prof. Richard R. Brock, Univ. of Calif., Irvine, Calif. 92650.
 - (d) Experimental and theoretical research.

- (e) Experimental data have been obtained on the growth of roll waves in channels as functions of Froude number and distance along the channel. Wave form has been measured and compared with that given by theory and the theory has been modified to take account of the gravity force on the waves.
- (f) Completed.
- (h) "Development of Roll-Wave Trains in Open Channels," J. of Hyd. Div., Proc. of ASCE, Vol. 95, No. HY4, July 1969, pp. 1401-1427, Richard R. Brock.

(6582)
TURBULENCE MEASUREMENTS IN WATER.

- (c) Professor Fredric Raichlen.
- (d) Experimental.
- (e) This study involves the use of a constant-temperature hot-film anemometer to measure the turbulence characteristics in water. The recording and reduction of data has been accomplished using the IBM 7094-7040 digital computing system and its peripheral analogue-to-digital conversion equipment located in the Booth Computing Center. The electrical signal from the associated electronics of the hot-film anemometer is connected directly to the Computing Center. The local temporal mean velocities, root mean squares of the turbulent velocity fluctuations, turbulent energy spectra, and autocorrelation curves were obtained directly from the digital computer.
- (f) Completed.
- (g) The results of the initial studies have shown relatively good agreement with the work of others in air. Since a major objective of this research is to develop a reliable method of measuring the turbulence characteristics of water, additional studies are planned.
- (h) "Some Turbulence Measurements in Water," F. Raichlen, J. Engrg. Mechanics Div., Proc. ASCE, Vol. 93, No. EM2, April, 1967. Discussion of "Some Turbulence Measurements in Water," F. Raichlen, J. J. Lee, J. Engrg., Mechanics Div., Proc. ASCE, Vol. 93, No. EM6, Dec. 1967.

(6583)
LABORATORY STUDIES OF THE EFFECT OF WAVES ON THE PROPOSED ISLAND SITE FOR A COMBINED NUCLEAR POWER AND DESALTING PLANT IN SOUTHERN CALIFORNIA.

- (b) The Bechtel Corporation.
- (c) Prof. Vito A. Vanoni and Prof. Fredric Raichlen.
- (d) Experimental.
- (e) The objectives of the studies were (1) to develop a design for the island face that will be stable under the attack of storm waves, (2) to determine the heights of the island faces needed to prevent overtopping by storm waves and (3) determine the effect of the proposed island on the littoral drift on the beach near the island. The stability of the island and overtopping by waves were studied by subjecting a one-fiftieth size model of a section of the face to properly scaled waves in a tank 114 feet long and 4 feet wide. Overtopping by obliquely incident waves and the effect of the island on littoral drift were studied in a 1:150 scale model of the island in a basin 145 feet wide by 160 feet long.
- (f) Completed.
- (h) "Laboratory Design-Studies of the Effect of Waves on a Proposed Island Site for a Combined Nuclear Power and Desalting Plant," V. A. Vanoni and F. Raichlen, W. M. Keck Lab. of Hyd. and Water Res., Report KH-R-14, July, 1966.

(6584)

WAVE UPLIFT FORCES ON DOCKS.

- (b) Sloan Foundation; Bechtel Foundation; National Science Foundation.
- (c) Prof. Fredric Raichlen and Mr. Jonathan A. French.
- (d) Experimental and theoretical.
- (e) A pile-supported pier in an exposed location is occasionally subject to high waves which impinge on its underside. At any particular location on a pier these waves cause a transient pressure consisting of a high-intensity portion of short duration followed by a lower pressure of longer duration. This latter portion exists until the rear portion of the wave separates from the dock and may be negative as well as positive. The specific objective of this research is to study theoretically and experimentally this pressure distribution with particular attention being given to the portion of high intensity which coincides with the initial wetting of the underside of the pier. Experiments are being conducted in a wave tank for the case of a solitary wave striking the underside of a dock which is represented by a flat plate located at fixed distance above the water surface. Simultaneous recordings are made of the wave profile and the resultant pressure distribution at locations on the underside of the platform as the wave travels underneath and in contact with it.
- (f) Inactive.
- (h) "Wave Uplift Pressures on Horizontal Platforms," Jonathan A. French, Rep. KH-R-19, Calif. Inst. of Tech., July 1969. Also Ph.D. thesis by same title and author, July 1969, available from University Microfilms, Inc., 313 No. 1st St., Ann Arbor, Mich.

(7144)

BASIC RESEARCH IN SEDIMENTATION.

- (b) National Science Foundation.
- (c) Prof. V. A. Vanoni, Prof. N. H. Brooks, or B. D. Taylor.
- (d) Experimental and theoretical research.
- (e) Flume studies are made to determine the effect of water temperature on characteristics of flows over sand beds. This involves observations of flow resistance, bed forms and sediment discharge.
- (h) Discussion by B. D. Taylor and V. A. Vanoni of paper by John J. Franco on "Effects of Water Temperature on Bed-Load Movement," J. Waterways and Harbors Div., Proc. ASCE, Vol. 95, No. WW2, May 1969, pp. 247-255.

(7145)

GENERATION, PROPAGATION AND COASTAL EFFECTS OF TSUNAMIS.

- (b) National Science Foundation.
- (c) Prof. F. Raichlen or J. Hammack.
- (d) Experimental and theoretical research.
- (e) Tsunami waves are generated at one end of a wave tank by the vertical displacement of a short section of the bottom according to a predetermined program. The propagation of the wave is observed throughout the flume.
- (g) The highly dispersive waves developed by an exponential type of bottom displacement have been observed over the 100-foot length of the tank.

(7146)

MIXING IN RIVERS AND ESTUARIES.

- (b) Federal Water Pollution Control Administration.
- (c) Professor Norman H. Brooks.
- (d) Experimental and theoretical research.

- (e) Previous research on longitudinal dispersion in natural channels (by Fischer) demonstrated the importance of transverse turbulent diffusion as part of the mechanism of longitudinal dispersion or mixing. Two types of flume experiments on transverse diffusion are being conducted.
- (g) In the first kind of experiments (by Okoye), a plume of a neutrally buoyant tracer was released at a point on the centerline of the flow in a wide flume. The distribution of tracer in downstream cross-sections is measured with in-situ probes and with overhead photographs. The results give the total transverse diffusion coefficient, and its decomposition into plume growth and plume meandering.
- In the second kind of experiments (by Prych), the tracer is either heavier or lighter than the ambient water, and the injector is a full-depth slit. The density difference accelerates the lateral spreading significantly during the early stages by gravity-driven secondary currents. The excess spreading due to density difference can be related in a dimensionless manner to a source strength parameter and injector width-to-depth ratio.
- (h) "Dispersion Predictions in Natural Streams," Hugo B. Fischer, J. San. Engrg. Div., ASCE, Vol. 94, SA5, Oct. 1968, pp. 927-943.
- Discussion of "Numerical Studies of Unsteady Dispersion in Estuaries," Donald R. F. Harleman, Chok-Hung Lee and Lawrence C. Hall, by Edmund A. Prych, J. San. Engrg. Div., ASCE, Vol. 95, No. SA5, Oct. 1969, pp. 959-964.
- (7147)
TURBULENT BUOYANT PLUMES AND JETS.
- (b) Federal Water Pollution Control Administration.
- (c) Professor Norman H. Brooks.
- (d) Theoretical and experimental laboratory research.
- (e) Problems of buoyant jets and plumes in density-stratified environments are being investigated for both two- and three-dimensional cases. Laminar cases are studied as well as turbulent. The results are applicable to certain problems of waste water or cooling water disposal in lakes, estuaries and the ocean.
- (g) The work on mechanics of buoyant plumes and jets has continued with production of a laboratory report by Fan and Brooks, giving extensive numerical results in dimensionless form for a wide variety of two- and three-dimensional buoyant jet discharges into linearly stratified environments (without ambient currents). For many cases the linear stratification assumption used in the Fan and Brooks report is too restrictive. Thus, a universal computer program (in Fortran IV language for IBM 360/75) has been developed by Dittmars to handle a wide range of round jets, with either positive or negative buoyancy, and discharge at any angle at any position relative to any arbitrary density profile in a large body of water.
- (h) "Numerical Solutions of Turbulent Buoyant Jet Problems," Loh-Nien Fan and Norman H. Brooks, W. M. Keck Lab. of Hyd. and Water Res., Report No. KH-R-18, Calif. Inst. of Tech., January 1969.
- "Computer Program for Round Buoyant Jets into Stratified Ambient Environments," John D. Dittmars, W. M. Keck Lab., Tech. Memo 69-1, March 1969.
- Discussion of "Physical Interpretation of Jet Dilution Parameters," James J. Sharp, by Loh-Nien Fan and Norman H. Brooks, J. Sanitary Engrg. Div., ASCE, Vol. 94, No. SA6, pp. 1295-1299, Dec. 1968.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91103. Dr. W. H. Pickering, Laboratory Director.

(7394)

HYDRAULIC CHARACTERISTICS OF FLOW THROUGH MINIATURE SLOT ORIFICES.

- (c) R. W. Riebling and W. B. Powell, Liquid Propulsion Section.
- (d) Experimental investigation and analytical correlation; applied research.
- (e) The hydraulic characteristics of miniature slot orifices of relatively short length and high aspect (width-to-height) ratio were studied experimentally. The effects of orifice dimensions, surface finish, and flow rates on discharge coefficients and flow regimes were determined. In addition, the stability and visual characteristics of the liquid streams were observed. Orifice surface finish and length-to-height ratio were found to exert a primary influence on hydraulic behavior, and the flow from these devices was predominantly within the transition region. The results are directly applicable to the design of rocket engine injectors incorporating this type of orifice.
- (f) Completed.
- (h) "The Hydraulic Characteristics of Flow Through Miniature Slot Orifices," R. W. Riebling and W. B. Powell, JPL - TR 32-1397, Sept. 1969. A paper based on this report will be presented at the AIAA 6th Propulsion Joint Specialists Conference, June 15-17, 1970, San Diego, California.

UNIVERSITY OF CALIFORNIA, BERKELEY, College of Engineering, Department of Naval Architecture, Berkeley, California 94720. Professor J. R. Paulling, Department Chairman.

(4084)

SHIPS OF MINIMUM RESISTANCE.

- (b) Office of Naval Research.
- (c) Professor J. V. Wehausen.
- (d) Theoretical and experimental; applied research; doctoral thesis.
- (e) The general aim of this work is to find computer designed ships of minimum "total" resistance, subject to various restraining conditions. Here "total" resistance means the Michell wave resistance plus the equivalent flat-plate frictional resistance.
- (g) Wave resistance measurements obtained from transverse profiles by means of stereo-photogrammetry showed a low wave resistance in the neighborhood of the design speed for three ships calculated to be of minimum resistance. The wave-resistance curves were much closer in behavior to the Michell resistance curves than to the residuary resistance. (This was not the case with a Series 60, block 60 model, however.) Further tests have been made with one of the models with suction slots near the stern and longitudinal-profile measurements for the wave resistance.
- (h) "Measurement by Transverse Wave Profiles of the Wave Resistance of Three Forms of 'Minimum' Resistance and of Series 60, Block 0.60," Sander Calisal, Francis H. Moffit, and John V. Wehausen, College of Engrg., Univ. of Calif., Berkeley, Report No. NA 68-1, Contract Nonr-3656(17), July 1968.
- "Resistance Studies of a Ship Model with Boundary-Layer Suction," Sander Calisal, College of Engrg., Univ. of Calif., Berkeley, Rep. No. NA 69-1, Con-

(4971)

SHIP RESISTANCE IN IRREGULAR WAVES.

- (b) Naval Ship Research and Development Center.
- (c) Mr. O. J. Sibul.
- (d) Experimental; applied research.
- (e) The previous resistance measurements of ship models in uniform waves will be used to predict the total added resistance in irregular waves of known spectral content. The predictions will be compared with experiments in irregular waves of various spectral contents and severity, combined with a number of model speeds.
- (g) The resistance response function was used to predict the resistance for series 60, $C_B = 0.70$ and $C_B = 0.80$ and for a slender hull with $C_B = 0.49$. The actual resistance increase was measured in a number of sea states. The results indicate that the predictions by the linear method for series 60 models are about 65 to 75 percent of the measured values for higher speeds and 55 to 60 percent for lower speeds. For the slender hull the prediction could be as low as 30 percent of the measurements.
- (h) "Ship Resistance in Irregular Waves," O. J. Sibul. Paper presented to the 12th Intl. Towing Tank Conf., Rome, Italy, September 1969.

(6300)

FORCES AND PRESSURES ON TWO-DIMENSIONAL BODIES IN FORCED OSCILLATIONS.

- (b) Naval Ship Research and Development Center.
- (d) Theoretical and experimental; doctoral theses.
- (e) A solution, accurate to the second order in amplitude of motion, is sought for a horizontal cylinder making periodic oscillations in heave, sway and yaw. Both pressure distribution, total force and moment, and the generated waves are sought. Appropriate experimental measurements which can be compared with theoretical results will also be made.
- (g) The theoretical analysis for pure heaving has already been completed, the computations for three degrees of motions are almost ready. Preliminary experiments have indicated the feasibility of measuring the contribution of second-order effects.
- (h) "The Second-Order Theory of Heaving Cylinders in a Free Surface," Chung Mook Lee, J. Ship Res., SNAME, Vol. 12, No. 4, pp. 313-327, Dec. 1968.

(7190)

STABILITY AND SHIP MOTION IN A SEAWAY.

- (b) U. S. Coast Guard, Department of Transportation.
- (d) Theoretical and experimental applied research.
- (e) Theoretical analyses are being made of ship motions in random waves on arbitrary course heading. Nonlinear and linear mathematical models are being developed. Experiments will be conducted using large radio controlled models in open water.
- (g) Results of nonlinear analyses indicate that unstable motion may occur with linearly stable equations of motion.

(7191)

CALCULATION OF THREE-DIMENSIONAL SHIP'S BOUNDARY LAYERS.

- (d) Theoretical; doctoral thesis.
- (e) A program is being written to apply a modification of the method of Compsty and Head to the calculation of the boundary layer on a ship hull. The effect of the free surface is taken into account.

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UNIVERSITY OF CALIFORNIA, BERKELEY, College of Engineering, Department of Civil Engineering, Division of Hydraulic and Sanitary Engineering, Berkeley, California 94720. Professor J. W. Johnson.

(1554)

SEA WATER CONVERSION RESEARCH.

- (b) State of California.
- (c) Professor Alan D. K. Laird, Coordinator, Saline Water Conversion Research, University of California, 1301 S. 46th St., Richmond, California.
- (e) The purpose of this project is to discover whether there is available any method for the large-scale, low-cost demineralization of sea water. The project includes a number of investigations, of which the following have been active during 1967-1969: (1) multiple-effect flash evaporator; (2) vapor compression distillation; (3) studies of heat transfer and scaling in distillation equipment; (4) transport phenomena near a liquid-vapor interface; (5) thermodynamic and economic analysis; (6) studies of the thermodynamic properties of sea water; (7) solar distillation; (8) fundamental studies of corrosion processes; (9) electro-dialysis; (10) reverse osmosis; and (11) ion exchange. Investigations are being carried on at the Berkeley, Los Angeles, Riverside, and San Diego Campuses.
- (g) Detailed results may be obtained from the progress reports and publications listed below. This project has been active since 1951-52 and previous summaries have listed all reports prior to Oct. 1967.
- (h) Reports and publications since October 1967 summarizing the work to date:
 *University of California, Los Angeles:
 "Corrosion Studies - Part XV - Passivity of Iron and Nickel; Part XVI - Corrosion Inhibition of Armo Iron; Part XVII - Co-Deposition Kinetics of Antimony and Hydrogen; Part XVIII - Corrosion Kinetics of Maraging Steel; Part XIX - Corrosion Kinetics of Indium," K. Nobe, School of Engrg. and Applied Science Rept. No. 67-46, 132 pp., Nov. 1967.
 "Mass Transport of Binary Electrolytes in Membranes: Concentration Dependence for NaCl Transport in Cellulose Acetate," D. N. Bennion, School of Engineering and Applied Science Report No. 67-55, 35 pp., October 1967.
 "Identification of Aquifer Parameters by Decomposition and Multilevel Optimization," Y. Y. Haimes, R. L. Perrine, D. A. Wismer, School of Engineering and Applied Science Rept. No. 67-63, 53 pp., Mar. 1968.
 "Saline Water Research Progress Summary," School of Engineering and Applied Science Report No. 68-1, 79 pp., January 1968.
 "Saline Water Research Progress Summary," School of Engineering and Applied Science Report No. 69-1, 74 pp., January 1969.
 "Three and One-Half Years' Experience with Reverse Osmosis at Coaliga, California," J. S. Johnson, J. W. McCutchan, D. N. Bennion, School of Engineering and Applied Science Rept. No. 69-45, 50 pp., July 1969.
 "Mass Transfer of Binary Electrolytes in Membranes Concentration Dependence," J. Osborn, D. N. Bennion, School of Engineering and Applied Science Report No. 69-49, 98 pp., August 1969.
 "Scale Abatement of Saline Water Distillation by Injection of Copper Dioxide," R. D. Ellis, School of Engineering and Applied Science Report No. 69-61, 113 pp., October 1969.
 "Saline Water Research Progress Summary," School of Engineering and Applied Science Report No. 70-1, 113 pp., January 1970.

- **University of California, Berkeley:**
 "Vapor-Compression Distillation - Part I. Analyses and Tests of Small Vapor-Compression Distillers," B. W. Tleimat, A. D. K. Laird, E. D. Howe;
 "Part II. Studies of Scale-Prevention in a Vapor-Compression Pilot-Plant Still Using Ion-Exchange Pretreatment of Seawater Feed," G. Klein, T. Vermeulen, Sea Water Conversion Lab. Rept. No. 67-3.
 "Multicomponent Diffusion: Generalized Theory with Ion-Exchange Applications," R. N. Clazie, G. Klein, T. Vermeulen, Sea Water Conversion Lab. Report No. 67-4, 258 pp., October 1967.
 "Progress Report - Berkeley, Riverside, and San Diego Campuses (1967)," Sea Water Conversion Lab. Report No. 68-1, 71 pp., January 1968.
 "Design and Cost of Ion-Exchange Softening for a 50-mgd Sea-Water Evaporation Plant," G. Klein, et al., Sea Water Conversion Lab. Report No. 68-2, 59 pp., September 1968.
 "Electrical Properties of Electrodialysis Membranes," R. A. Wallace, Sea Water Conversion Lab. Report No. 68-3, 41 pp., September 1968.
 "Multiple Effect Flash (MEF) Evaporator," L. A. Bromley, Sea Water Conversion Lab. Report No. 68-4, 86 pp., December 1968.
 "1968 Progress Report - Berkeley, Riverside and San Diego Campuses," Sea Water Conversion Lab. Report No. 69-1, 67 pp., January 1969.
 "The Solubility of Carbon Dioxide in Distilled Water, Synthetic Sea Water and Synthetic Sea Water Concentrates," P. B. Stewart and P. K. Munjal, Sea Water Conversion Lab. Rept. 69-2, 44 pp., July 1969.
 "Condensation On and Evaporation from a Rotating Flat-Disk Wiped-Film Evaporator," B. W. Tleimat, Sea Water Conversion Lab. Rept. 69-3, 20 pp., Sept. 1969.
 "1969 Progress Report - Berkeley, Riverside and San Diego Campuses," Sea Water Conversion Lab. Report 70-1, January 1970.
 "An Assessment of Vapor Compression Distillation," B. W. Tleimat, E. D. Howe, A. D. K. Laird, Desalination, Vol. 2, pp. 287-298, 1967.
 "Comparison of Plastic and Glass Condensing Covers for Solar Distillers," B. W. Tleimat and E. D. Howe, Solar Energy, Vol. 21, pp. 293-304, 1967.
 "Electrical Conductivity of Polystyrenesulfonate Membranes," C. S. Fadley and R. A. Wallace, J. Electrochem. Soc., 115 No. 12, pp. 1264-1270, 1968.
 "Calcium Removal from Sea Water by Fixed-Bed Ion Exchange," G. Klein, et al., Desalination, 4, No. 2, pp. 158-166, 1968.
 "Dielectric Properties of Ionic Membranes," Z. Urban and R. A. Wallace, J. Electrochem. Soc., 115 No. 3, pp. 276-279, 1968.
 "Determination of Carbon Dioxide in Aqueous Solutions Under Pressure," P. B. Stewart, P. K. Munjal and F. Quiring, Analytical Chemistry, 41, No. 12, pp. 1710-1711, 1969.
 "Effects of Construction and Maintenance on Performance of Solar Distillers," B. W. Tleimat, ASME Publ. No. 69-WA/Sol-4, 5 pp., November 1969.
 "Novel Approach to Desalination Vapor-Compression Distillation," B. W. Tleimat, ASME Publication No. 69-WA/FPD-1, 12 pp. November 1969.
 *Requests for copies should be directed to:
 Institute of Industrial Cooperation, School of Engineering and Applied Science, University of California, Los Angeles, California 90024.
 **Requests for copies should be directed to:
 Sea Water Conversion Lab., University of California, 1301 S. 46th Street, Richmond, California 94804.
- (2265)
FORCES ON ACCELERATED CYLINDERS.
 (c) Professor A. D. K. Laird. (See (1554).)
 (d) Experimental and theoretical; basic research.
 (e) Measurement and prediction of drag coefficients and flow configurations about cylinders in fluids, including effects of support flexibility.
 (g) Analytical explanation of eddy formation found.
- (4562)
ANALYSIS OF NONLINEAR SYSTEMS.
 (b) Water Resources Center, Univ. of Calif.
 (c) Professor J. A. Harder.
 (d) Theoretical; basic research.
 (e) Given a sufficiently long record of the input and output of a stationary system that may include nonlinearities, the purpose is to develop a predictor for arbitrary inputs.
 (f) Completed.
 (g) Computer program has been developed. Applications have been made to the prediction of salinity in estuaries from river flow data. Predictor accuracy is of same order of accuracy as field data (5 - 10%).
 (h) "The Identification of Nonlinear Hydrologic Systems," J. A. Harder and S. Zand, Hyd. Eng. Lab., Tech. Rept. HEL-8-2, March 1969.
- (4565)
MATHEMATICAL MODELS FOR FLOOD ROUTING.
 (b) Water Resources Center, University of California.
 (c) Professor J. A. Harder.
 (d) Theoretical; basic research.
 (e) Computer simulation of flood flows through natural channels is compared with actual flows.
 (g) Computer programs are operating successfully and a generalized theory is being worked out.
- (4930)
COASTAL SAND MOVEMENT.
 (b) Corps of Engrs., U. S. Army, Coastal Engr. Research Center.
 (d) Experimental; laboratory and field.
 (e) This investigation is concerned with the transportation of sand by both wind and waves.
 (h) "Recent Sediments of Monterey Bay, California," T. E. Yancey, University of California, Hyd. Engrg. Lab., Rept. HEL-2-18, July 1968.
 "Recent Sediments of Bolinas Bay, California," C. Isselhardt, L. Osuch, T. Yancey, and P. Wilde, Part I - Introduction and Grain Size Analysis, Hyd. Engrg. Lab. Rept. HEL-2-19, November 1968.
 Part II - Mineralogical Data, Hyd. Engrg. Lab. Rept. HEL-2-22, April 1969. Part III - Interpretation and Summary of Results, Hyd. Engrg. Lab. Rept. HEL-2-23, September 1969.
 "Extended Application of a Single Hot-Film Probe for the Measurement of Turbulence in a Flow Without Mean Velocity," M. M. Das, University of California, Hyd. Engrg. Lab., Rept. HEL-2-20, December 1968.
 "History of Shore Growth from Analysis of Aerial Photographs," F. H. Moffitt, University of California, Hyd. Engrg. Lab., Rept. HEL-2-21, December 1968 (also see Shore and Beach, pp. 23-27, April 1969).
 "Prediction of Bottom Current Velocities from Sediment Deposits on the Sea Bed," N. N. Panicker, University of California, Hyd. Engrg. Lab., Rept. HEL-2-24, November 1969.

- (4932)
GROUND WATER BASIN MANAGEMENT.
(b) Office of Water Resources Research; and Water Resources Center.
(c) D. K. Todd.
(d) Theoretical; applied research.
(e) Equations were derived and solved to study the dispersion of the fresh-salt water interface due to tidal fluctuations in a confined aquifer. The goal is a generalized mathematical model describing a two-dimensional aquifer system, the longitudinal and transverse dispersion coefficients, and the dispersion caused by local movements of the interface and by tidal fluctuations.

(4934)

WAVE DIFFRACTION AND REFRACTION.

- (b) Corps of Engrs., U.S. Army, Coastal Engrg. Research Center.
(c) Professor R. L. Wiegel.
(d) Experimental and theoretical; basic research.
(e) Determination by model tests of diffraction and refraction characteristics of wind waves. Computer simulation program for waves with directional spectra.
(g) A study is being made on the directional spectra of wind generated waves, and on their diffraction by a semi-infinite breakwater. Theoretical studies are being conducted on the properties of direction of wave spectra, and methods of simulating such waves on a digital computer.
(h) "Computer Solution of Wave Diffraction by Semi-Infinite Breakwater," Shou-shan Fan, J. D. Cumming, and R. L. Wiegel, Univ. of Calif., Hyd. Eng. Lab., Tech. Rept. HEL 1-8, 376 pp., October 1967.
"Diffraction of Wind Waves," Shou-shan Fan, Univ. of Calif., Hyd. Eng. Lab., Tech. Rept. HEL 1-10, 175 pp., August 1968.
"Determination of Approximate Directional Spectra for Surface Winds," Yoshimi Suzuki, Univ. of Calif., Hyd. Eng. Lab., Tech. Rept. HEL 1-11, 47 pp., August 1968.
"Water Waves Over a Rectangular Channel Through a Reef," Nabil Hilaly, J. Waterways and Harbors Div. Proc. ASCE, Vol. 95, No. WW1, pp. 77-94, February 1969.
"Directional Spectra Models for Design Use for Surface Waves," L. E. Borgman, Univ. of Calif., Hyd. Eng. Lab., Tech. Rept. HEL 1-12, 56 pp., June 1969. Also published in 1969 Offshore Technology Conference - Preprints, Vol. 1, pp. 721-746, May 1969.
"Comparison of Wind Wave and Uniform Wave Effects on a Beach," Peter Truman Kraal, Shore and Beach, Vol. 37, No. 2, pp. 60-71, October 1969.
"Design Study for a Suggested Wave Gage Array Off Point Mugu, California," L. E. Borgman and N. N. Panicker, Univ. of Calif., Hyd. Eng. Lab., Tech. Rept. HEL 1-14, 23 pp., January 1970.

(5437)

DEPOSIT OF SILT IN A GRAVEL BED BY WATER FLOWING OVER THE BED.

- (b) U.S. Bureau of Reclamation.
(c) Professor H. A. Einstein.
(d) Experimental; basic research.
(e) The rate at which fine sediment is deposited in artificial spawning grounds for salmon and other fish has been determined. The sediment carrying flow is recirculated over gravel beds in laboratory flumes.
(f) Terminated.
(g) The fine sediment deposits at a rate that is proportional to the concentration. The concentration

decreases exponentially. The "half life" is proportional to the water depth and inversely proportional to the settling velocity.
(h) "Deposition of Suspended Particles in a Gravel Bed," H. A. Einstein, Jour. Hydraulics Division, American Society of Civil Engineers, Paper 6102, September 1968.

(5438)

SHAPE OF CROSS SECTIONS IN RIVER BENDS.

- (b) California State Water Resources Center.
(c) Professor H. A. Einstein.
(d) Experimental with statistical analysis, Ph.D. thesis.
(e) A circular flume has been constructed in which various flows are established and cross-sections established. The cross-sections are statistically described by a minimum of parameters and the change of these parameters established in terms of the flow and sediment parameters. River sections are equally analyzed.
(g) Analysis of 2300 cross-sections of the Missouri River shows that cross-slope of the bed can be predicted as a function of the channel curvature in the preceding 1.5 miles of river. The statistical analysis is continued.

(5439)

WAVE FORCES.

- (b) Corps of Engrs., U.S. Army, Coastal Engrg. Research Center.
(c) Professor R. L. Wiegel.
(d) Experimental and theoretical; basic research.
(e) Determine by model tests the forces exerted by waves on coastal structures. Theoretical studies of statistical properties of wave forces.
(g) Forces exerted by waves on piles are being studied experimentally. Spectral methods are being developed to study wave forces on piles, both theoretically and experimentally. The relationship between the Keulegan number, the longitudinal and transverse forces exerted by waves on piles is also being studied in the laboratory.
(h) "Ocean Wave Simulation for Engineering Design," Leon Emry Borgman, Proc. Conf. on Civil Engrg. in the Oceans, San Francisco, California, September 6-8, 1967, ASCE, pp. 31-74, 1968.
"Predicting Wave Responses of Deep-Ocean Towers," E. T. Foster, Proc. Conf. on Civil Engrg. in the Oceans, San Francisco, California, September 6-8, 1967, ASCE, pp. 75-93, 1968.
"Tsunami Surge Forces," Ralph H. Cross, J. Waterways and Harbors Div., Proc. ASCE, Vol. 93, No. WW4, pp. 201-234, November 1967.
"Laboratory Study of Inertia Forces on a Pile," Yuan Jen, J. Waterways and Harbors Div., Proc. ASCE, Vol. 94, No. WW1, pp. 59-76, February 1968.
"Waves and Their Effects on Pile-Supported Structures," R. L. Wiegel, Symp. on Research on Wave Action, Vol. 1, General Lecture, Delft Hydraulics Lab., Delft, The Netherlands, pp. 1-43, July 1969.

(5817)

SHIP WAVES IN NAVIGATION CHANNELS.

- (b) Coastal Engineering Research Center.
(c) Professor J. W. Johnson.
(d) Theoretical, laboratory and field experimental basic research study.
(e) The characteristics of waves generated by ships moving at various speeds in shallow water are being investigated.
(f) Completed.
(h) "Ship Waves in Shoaling Water," D. D. Bidde, Univ. of Calif., Hyd. Engrg. Lab. Rept. HEL-12-6, Jan. 1968.

- "Ship Waves at Recreational Beaches," J. W. Johnson, University of California, Hyd. Engrg. Lab. Rept. HEL-12-7, April 1968 (also see Shore and Beach, April 1969, pp. 11-15).
- "Mapping of Ship Waves Breaking on a Beach," F. H. Moffitt, University of California, Hyd. Engrg. Lab. Rept. HEL-12-8, December 1968.
- "Relative Effect of Waves Generated by Large Ships and Small Boats in Restricted Waterways," M. M. Das, Univ. of Calif., Hyd. Engrg. Lab. Rept. HEL-12-9, November 1969.
- "Ship Waves in Navigable Waterways," Duncan Hay, Proc. 11th Conf. on Coastal Engrg., Chap. 95, 1969.
- "Ship Waves in Shoaling Water," J. W. Johnson, Proc. 11th Conf. on Coastal Engrg., Chap. 96, 1969.
- "Waves Generated by Model Ship Hull," R. M. Sorensen, J. Waterways and Harbors Div., ASCE, Nov. 1969, pp. 513-538.

(5820)

TRANSPORT OF SILT THROUGH POROUS MEDIA.

- (b) National Science Foundation.
- (c) Professor H. A. Einstein.
- (d) Experimental and theoretical basic research.
- (e) Silt-carrying water is flowing at various directions through porous media. The deposition, transport and erosion of the silt are studied as a function of silt size, concentration and density, and of the flow velocity.
- (f) Completed.
- (g) Laboratory experiments in a column filled with spheres in geometrically regular arrangement are concluded and show that particles smaller than 1/7 of their diameter are able to enter the pores. Particles between 1/7 and 1/14 their size will in time clog the column. Particles smaller than 1/14 their size will indefinitely pass through the column. For horizontal or near horizontal motion there exists a relationship between the rate of motion of the fine particles and the fluid velocity.
- (h) "Clogging of Porous Column of Spheres by Sediment," Ramaswamy Sakthivadivel and H. A. Einstein, J. Hyd. Div., ASCE, Vol. 96, No. HY2, pp. 461-472, February 1970.

(6221)

ENERGY DISSIPATORS FOR LARGE CULVERTS.

- (b) California Division of Highways.
- (c) J. W. Johnson.
- (d) Experimental.
- (e) Model studies were conducted to arrive at the best condition for a hook-type dissipator with Froude numbers up to about four.
- (f) Completed.
- (h) "Energy Dissipators for Large Culverts," T. C. MacDonald, J. Hyd. Div., ASCE, pp. 1941-1969, November 1969.

(6222)

FEEDBACK CONTROL OF CANAL GATES.

- (b) U.S. Bureau of Reclamation, Region II.
- (c) Professor J. A. Harder.
- (d) Experimental; applied research.
- (e) Canal systems are modeled with electric analogs and digital computer programs, and feedback control systems for maintaining near-constant water levels are developed and evaluated.
- (f) Completed.
- (g) A feedback loop filter constructed of hydraulic components has been developed that successfully controls oscillations.
- (h) "The Hydraulic Filter Level Offset Method for the

Feedback Control of Canal Checks," M. J. Shand, University of California, Hyd. Eng. Lab., Tech. Rept. HEL-8-3, June 1968.

(6223)

THE MANAGEMENT OF SURFACE WATER HYDROLOGIC SYSTEMS FOR WATER QUALITY CONTROL.

- (b) Water Resources Center, University of California.
- (c) Hugo B. Fischer, Assistant Professor.
- (d) Experimental and theoretical; basic research.
- (e) Basic mechanics of mixing and dispersion of pollutants in river and estuarine systems are studied to improve methods of predicting and managing surface water quality.
- (h) "A Method for Predicting Pollutant Transport in Tidal Waters," Hugo B. Fischer, Water Resources Center Contribution No. 132, University of California, Berkeley.

(6224)

TSUNAMIS.

- (b) Corps of Engrs., U.S. Army, Coastal Engrg. Research Center.
- (c) Professor R. L. Wiegel.
- (d) Experimental and theoretical; basic research.
- (e) Model and theoretical studies of water waves generated by horizontal fault moving normal to a channel or escarpment, and generated by a rockfall into a reservoir.
- (g) See (e).
- (h) "Tide Gage Frequency Response," Ralph H. Cross, J. Waterways and Harbors Div., Proc. ASCE, Vol. 94, No. WW3, pp. 317-330.
- "A Hydraulic Model Study of Landslide-Generated Water Waves in Bays," Edward M. Kuba, Shore and Beach, Vol. 37, No. 1, pp. 49-54, April 1969.
- "Theory of Water Waves Generated by a Time-Dependent Boundary Displacement," Edward Noda, University of California, Hyd. Eng. Lab. Tech. Rept. HEL 16-5, 225 pp., October 1969.

(7148)

MIXING PROCESSES IN ESTUARIES.

- (b) National Science Foundation.
- (c) Hugo B. Fischer, Assistant Professor.
- (d) Experimental and theoretical; basic research.
- (e) Studies are made of the convective and diffusive patterns in estuaries to find ways of predicting pollutant concentrations.
- (h) "Cross-Sectional Time Scales and Dispersion in Estuaries," Proc. Thirteenth Cong. Intl. Assoc. Hydraulic Research, Vol. 3, pp. 173-180, 1969.

(7149)

MANAGEMENT OF WATER QUALITY IN STRATIFIED RESERVOIRS.

- (b) Federal Water Pollution Control Administration.
- (c) Hugo B. Fischer, Assistant Professor.
- (d) Experimental and theoretical; basic research.
- (e) The withdrawal layer in a stratified reservoir is being restudied to assess the effects of inertia as well as buoyancy. Experiments in unsteady flow are planned.

(7150)

OPTIMAL DETERMINATION OF STRATIFIED GROUNDWATER BASIN CHARACTERISTICS.

- (b) National Science Foundation; Water Resources Center.
- (c) D. K. Todd.
- (d) Theoretical; applied research.
- (e) To estimate from historical data, values of S and T for individual wells in a given configuration for the purpose of optimal management of the basin. A computational algorithm will be designed, and it is proposed to solve it by de-

composition because of its high dimensionality.

(7151)

WASTE DISPOSAL SYSTEMS.

- (b) Water Resources Center.
- (c) Professor R. L. Wiegel.
- (d) Experimental, basic and applied research.
- (e) Perform model studies of the mixing processes associated with sewage effluent being discharged on ocean bottom and buoyant power plant cooling water being discharged at ocean surface.
- (g) Recently, laboratory studies of mixing surface jet, using hot-film anemometers, have shown that a considerable amount of turbulence in the plume is generated by an instability at the "interface" of the plume and the receiving water.
- (h) "Surface Discharge of Horizontal Warm-Water Jet," Y. Jen, R. L. Wiegel and I. Mobarek, J. Power Div., Proc. ASCE, Vol. 92, No. PO2, pp. 1-28, April 1966. "Horizontal Surface Discharge of Warm-Water Jets," Nobuyuki Tamai, Robert L. Wiegel and Gordon F. Tornberg, J. Power Div., Proc. ASCE, Vol. 95, No. PO2, pp. 253-276, October 1969.

(7152)

FLOATING BREAKWATER.

- (b) Department of Harbors and Watercraft, State of California.
- (c) Professor R. L. Wiegel.
- (d) Experimental, applied research.
- (e) Make a literature survey on work done on mobile breakwaters. Determine possible types for use in reservoirs, or develop new type and perform laboratory tests thereon.
- (f) Completed.
- (g) Two new types showed promise for the short waves normally expected in a reservoir.
- (h) "Preliminary Study of Mobile Breakwaters for Use in Lake and Reservoir Small Craft Harbors," Kenneth Chen, University of California, Hyd. Eng. Lab., Tech. Rept. HEL 20-1, 27 pp., January 1969. "Hydraulic Study of Five Floating Breakwaters for Use in Reservoirs," Kenneth Chen and R. L. Wiegel, Univ. of Calif., Hyd. Eng. Lab., Tech. Rept. HEL 20-2, 25 pp., September 1969. "Floating Breakwater for Reservoir Marinas," Kenneth Chen and R. L. Wiegel, to be published in Proc. Twelfth Conf. on Coastal Engrg., ASCE, 1970.

UNIVERSITY OF CALIFORNIA, BERKELEY, Department of Mechanical Engineering, Division of Aeronautical Sciences, Berkeley, California 94720. Professor M. Holt.

(7187)

THE EFFECTS OF DISSIPATION IN THE MOTION OF AN UNDULAR BORE.

- (b) Office of Naval Research.
- (c) Professor M. Holt and Dr. J. G. Byatt-Smith.
- (d) Theoretical; basic research.
- (e) The problem of the steady bore running down hill is considered. The effects of dissipation are included empirically using the Chezy Law. The method of solution is based on an averaging technique which assumes that the uniform solution is slowly varying.
- (f) Completed.
- (h) "The Effects of Dissipative Terms in the Solution of the Undular Bore," J. G. Byatt-Smith, Quarterly of Applied Math. (1970), to be published. University of California Aero Sci. Div. Rept. AS-69-9 April 1969.

(7188)

WAVES ON A THIN FILM OF VISCOUS LIQUID.

- (b) Office of Naval Research.
- (c) Professor M. Holt and Dr. J. G. Byatt-Smith.
- (d) Theoretical; basic research.
- (e) The flow of a viscous incompressible fluid down an inclined wall is studied. The solution is obtained by assuming the amplitude and frequency of the waves on the free surface are small. The solution is numerical and the results are compared with existing theories and available experimental results.
- (f) Completed.
- (g) The investigation showed that the method of approach was not valid for large Reynolds number where the flow was still laminar. At present research is being conducted in this flow regime.
- (h) "Waves on a Thin Film of Viscous Liquid," J. G. Byatt-Smith, Amer. Inst. Chem. Eng. J. (1970), to be published. Univ. of Calif. Aero Sci. Div. Rept. AS-69-4 February 1969.

(7189)

AN EXACT INTEGRAL EQUATION FOR STEADY SURFACE WAVES.

- (b) Office of Naval Research.
- (c) Professor M. Holt and Dr. J. G. Byatt-Smith.
- (d) Theoretical; basic research.
- (e) An exact integral equation is found for steady surface waves on an inviscid fluid.
- (f) Completed.
- (g) All existing approximations are easily derived from the one equation. A numerical solution is attempted in the case of the solitary wave. From the numerical solution the amplitude of the solitary wave of maximum height is estimated.
- (h) "An Exact Integral Equation for Steady Surface Waves," J. G. Byatt-Smith, Proc. Roy. Soc. (1970), to be published. University of California Aero Sci. Div. Rept. AS-69-3 February 1969.

UNIVERSITY OF CALIFORNIA, DAVIS, College of Agriculture and Environmental Science, Department of Water Science and Engineering, Davis, California 95616. Verne H. Scott, Department Chairman.

(5145)

GENERALIZED ANALYSIS OF SMALL WATERSHED RESPONSES.

- (b) Office of Water Resources Research, Water Resources Center, University of California.
- (c) Professor J. Amorcho.
- (d) Theoretical and experimental; basic and applied research.
- (e) (1) Studies on the mathematical theory of nonlinear systems with lumped and with distributed parameters; (2) development of methods for the establishment of inflow-outflow relationships for natural catchments; (3) laboratory and field investigations related to above.
- (f) Terminated.
- (g) A method for the determination of nonlinear response functions of small watersheds was developed and tested in laboratory catchments and in natural catchments.
- (h) "Determination of the Nonlinear Response Functions of Hydrologic Systems," J. Amorcho and Albin Brandstetter, Water Science and Engineering Paper No. 1035, Department of Water Science and Engineering, University of California, Davis.

- (5861)
THE MECHANICS OF OPEN CHANNEL FLOW SYSTEMS.
- (b) Office of Water Resources - Water Resources Center, University of California.
- (c) Professor Theodor S. Strelkoff (see part i) and Professor J. Amorochio and Mr. Alan Babb (see part ii), Department of Water Science and Engineering, University of California.
- (d) Theoretical and experimental investigation.
- (e) Comprehensive analytical and experimental study of phenomena encountered in the operation of complex open channel systems with multiple controls. Development of mathematical models of the systems for steady and unsteady state operation.
- (f) Completed.
- (g) 1. Explicit and implicit numerical methods have been established for calculation of gradually varied unsteady flows and flows subject to formation of bores in channels of arbitrary configuration with or without lateral discharge. Flow profiles and discharge coefficients have been obtained for a series of hydraulic structures--overfalls, gates, and sills-- by analytical means; comparison with experiment shows good agreement. A synthesis of gradually varied flow in long reaches with rapidly varied flow in structures results in a mathematical model of a complete open channel flow system, such as portions of the California Aqueduct. A comparison of results from such a model with empirical data taken in a portion of the Delta-Mendota Canal during operation of the Tracy pumping plant and a series of checks along the canal showed good agreement.
- ii. The work accomplished under this project falls under two general subjects: (1) study of flow phenomena in channel transitions, and (2) study of flow in the neighborhood of open channel gates and controls. The study of channel transitions yielded data on the variation of the energy losses for warped expansions at high Reynolds numbers, and furnished criteria regarding corrections for incomplete similitude in model investigations of these configurations. Detailed analyses of the fluid mechanics of expansions were advanced with the study of conical shapes. These investigations involved the development of special laboratory techniques and the evaluation of the terms of the integrated equations of energy and momentum balance for the flow in the expanding fields. The analysis of the results will lead to analytic methods for optimum transition design.
- The behavior of radial gates under a large variety of flow conditions was investigated with particular reference to multi-gated structures.
- (h) "Solution for Gravity Flow Under a Sluice Gate," Delmar D. Fangmeier, Theodor S. Strelkoff, J. Engrg. Mech. Div., ASCE, Vol. 94, No. EM 1, Proc. Paper 5797, February 1968, pp. 153-176.
- "Water-Surface Profiles in Rectangular Channels with Concentrated Partial Outflow Through a Bottom Slot," John Sakkas, M. S. thesis, University of California, Davis, 1968.
- "Gradually Varied Unsteady Flow in a Controlled Canal System," Theodor Strelkoff and J. Amorochio, Paper No. 3.16, Proc. XI Congr. Intl. Assoc. Hyd. Res. Leningrad, U.S.S.R., September 1965.
- "One-Dimensional Equation of Open-Channel Flow," Theodor Strelkoff, presented at ASCE Hydraulics Conf., Madison, Wisconsin, August 24-26, 1966.
- "Numerical Solution of the Saint Venant Equations," Theodor Strelkoff, J. Hyd. Div., Proc. ASCE, Vol. 96, No. HY1 Proc. Paper 7043, January 1970.
- "Pattern of Potential Flow in an Overfall," Theodor Strelkoff and M. S. Moayeri, J. Hyd. Div. Proc., ASCE, Vol. 96, HY4, April 1970, pp. 879-903.
- "Computation of Open-Channel Surges and Shocks," George Terzidis and Theodor Strelkoff, J. Hyd. Div., Proc. ASCE, in press.
- "Discussion of Technical Sessions Subject 3, Unsteady Flows in Open Channels," Theodor Strelkoff, Trans. XI Congr. Intl. Assoc. Hyd. Res., Leningrad, U.S.S.R., Vol. VI, pp. 317-320, Sept. 1965.
- "Hydraulic Transients in the California Aqueduct," J. Amorochio and Theodor S. Strelkoff, Rept. No. 2, Water Science and Engrg. Paper No. 1008, Dept. of Water Science and Engrg., Davis, June 1965.
- "Mechanics of Flow in Open Channel Systems," J. Amorochio and A. F. Babb, Summary Technical Report, Water Science and Engrg. Paper No. 1040:1-10, University of California, Davis, 1969.
- "A Mathematical Model of the California Aqueduct," J. Amorochio, Proc. Western Water and Power Symposium, Los Angeles, April 1968.
- "Air Modeling Techniques for Open Channel Transitions," J. Amorochio and Alan Babb, Water Science and Engrg. Paper No. 1036, Dept. of Water Science and Engrg., University of California, Davis, November 1969.
- "Hot Probe Anemometry for Flow in a Conical Diffuser," A. Babb and J. Amorochio, Water Science and Engrg. Paper No. 1038, Dept. of Water Science and Engrg., Univ. of Calif., Davis, Nov. 1969.
- "Some Flow Characteristics of Conical Diffusers," A. Babb and J. Amorochio, Water Science and Engrg. Paper No. 1037, Dept. of Water Science and Engrg., Univ. of Calif., Davis, November 1969.
- "Discharge Characteristics of Radial Gates in a Multiple-Gated Control Structure," J. Amorochio and A. Babb, Water Science and Engrg. Paper No. 1039, Dept. of Water Science and Engrg., Univ. of Calif., Davis, November 1969.
- (6664)
THEORY OF THE DESIGN OF PRECIPITATION NETWORKS FOR HYDROLOGIC ANALYSIS.
- (b) Water Resources Center, University of California.
- (c) Professor J. Amorochio.
- (d) Theoretical and experimental investigation; basic and applied research.
- (e) Experimental and analytical studies for the determination of the optimum design of precipitation networks for hydrologic analysis.
- (f) Terminated.
- (g) Weather radar information, together with the results of observations obtained from a dense rain-gage network in Northern California, led to the development of a model of cyclonic precipitation fields at ground level suitable for hydrologic applications. The required density of rain-gage networks for hydrologic use follows from the study of these fields.
- (h) "Comparison Between Rain Gage and Lysimeter Measurements," D. L. Morgan and F. J. Lourence, Water Resources Research, Vol. 5, No. 3, June 1969, pp. 724-728.
- (6665)
OPTIMIZATION OF CONJUNCTIVE SURFACE AND GROUND WATER USE.
- (c) Dr. Verne H. Scott and Dr. Gert Aron.
- (d) Theoretical and field research. Applied research including doctoral thesis studies.
- (e) Development of an operating schedule of a water

- distribution system including surface and ground water supplies for the purpose of optimizing long-term benefits; a study of water quality control by programmed conjunctive use of water supplies of different salt content.
- (f) Terminated.
- (g) The problems and available methods of optimizing the operation of a water resource system involving ground water use and recharge, local surface supply and an imported supply were outlined with particular emphasis on the technique of dynamic programming. Simplification of a large and complex system and subdivision of the system into various subsystems was suggested. Several methods of optimizing the operation were presented. Dynamic programming was proposed as the best method for developing a policy of optimal conjunction management of the subsystems. The optimization of a field model was completed which included three state and twelve decision variables and a sequential decision process extending over 40 time periods of three month duration.
- (h) "Optimization of Conjunctively Managed Surface and Ground Water Resources," Gert Aron, Water Resources Center Contribution No. 129, University of California, June 1969.
- "Optimization of Conjunctively Managed Surface and Ground Water Resources by Dynamic Programming," Gert Aron, Ph.D. thesis, July 1969.
- (7192)
EVALUATION OF WATER YIELD POTENTIAL IN EAST PUTAH CREEK WATERSHED.
- (b) Bureau of Land Management, and Bureau of Reclamation, U.S. Dept. of Interior; University of California.
- (c) Professor R. H. Burgy.
- (d) Developmental.
- (e) Gather basic resource data on the East Putah Creek Watershed and provide predictive relationships for water yield improvement potential and recommendations for a master plan and comprehensive resource management program involving watershed management and environmental quality considerations.
- (7193)
HYDRAULIC STUDIES AND WATERSHED MANAGEMENT ON BRUSH LANDS.
- (b) SDWR - University of California.
- (c) Professor R. H. Burgy.
- (d) Laboratory and field investigation; applied research.
- (e) Conduct investigations of the hydrology of intermediate elevation upland watersheds with basic and applied research on the several components of the hydrologic cycle and on the "before" and "after" hydrologic effects of converting watersheds from brush and timber to grass.
- (g) Precipitation - water yield relationships for prediction of hydrologic effects of vegetation management have been developed.
- (7194)
DRAINAGE DESIGN IN RELATION TO SOIL SALINITY.
- (b) Water Resources Center - University of California.
- (c) Dr. James N. Luthin.
- (d) Experimental and theoretical.
- (e) Develop alternative methods of managing the salt load of water used in irrigation agriculture to optimize the beneficial use of the water resources.
- (g) Existing data on salinity and water tables in the Imperial Valley has been used to synthesize an irrigation - drainage - salinity control system.
- (h) "Depth of Drainage in Irrigated Areas," James N. Luthin and Frank Robinson, Trans. ASAE, Vol. 12, No. 1, pp. 27, 28, and 31, January 1970.
- "Displacement Front Under Ponded Leaching," James N. Luthin, P. Fernandez, Boris Maslov, Jack Woerner, and Frank Robinson, Proc. ASCE, Vol. 95, No. IRI, Proc. Paper 6446, March 1969, pp. 117-125.
- (7195)
DRAINAGE DESIGN AS INFLUENCED BY CONDITIONS IN THE VICINITY OF THE DRAIN LINE.
- (b) OWRR - Water Resources Center - Univ. of Calif.
- (c) Dr. James N. Luthin.
- (e) Determine exit gradients causing movement of sands and silts into drain pipes for a variety of conditions; determine optimum size of gravel envelope; determine effect of crack width on flow into drain lines; and determine optimum spacing and location of perforations on drain lines.
- (7196)
SURGES IN DRY CHANNELS.
- (c) Dr. Theodor S. Strelkoff.
- (d) Theoretical, basic and applied, Ph.D. thesis.
- (e) A general numerical solution is sought for the movement of a water wave down a dry channel of arbitrary cross-section which may be hydraulically rough and pervious. Application to floods following dam break or cloud-burst storms; advance of irrigation water down a furrow or border. Central assumption is hydrostatic pressure distribution, shallow water theory. Finite-difference and characteristics method are under investigation.
- (g) Preliminary problem of catastrophic flooding of a channel initially containing a stream has been solved by method of characteristics with isolation and tracking of the bore and by finite-difference, "through" solution of integrated continuity and momentum equations.
- (7197)
SOLITARY WAVES OF CONSTANT FORM.
- (c) Dr. Theodor Strelkoff.
- (d) Theoretical/basic.
- (e) The two-dimensional solitary wave is transformed to the steady case by translating the coordinate system at the wave velocity. Potential flow is assumed and the free-surface zero-pressure condition is expressed exactly in terms of an integral of the free-surface elevation, approximately weighted. The result is an integral equation in the surface profile with wave velocity as a parameter set *a priori*. Expression of the integral in quadratures leads to a method of successive approximations for the wave shape. An algorithm is sought, in the limiting case of maximum wave height, for the appropriate wave velocity.
- (g) Profiles have been obtained for a range of amplitudes extending nearly to the maximum. The limiting case is still under consideration.
- (7198)
RUNOFF FROM ARID AND SEMIARID CLIMATE WATERSHEDS.
- (b) Dept. of Army, Corps of Engineers.
- (c) Dr. J. Amorcho.
- (d) Theoretical and experimental investigation; basic and applied research.
- (e) (1) Studies on the spatial and temporal distribution of convective storm precipitation; (2) development of models for precipitation fields from (1); (3) development of distributed parameter models for small arid watersheds with inputs from (2).

- (g) A convective storm model has been developed based on progress for the development of the hydrologic model.

(7199)

PHYSICAL, ECONOMIC AND ENVIRONMENTAL RELATIONSHIPS IN THE DESIGN OF ARTIFICIAL RECHARGE FACILITIES.

- (b) Water Resources Center - Univ. of Calif.
(c) Dr. Verne Scott, Dept. of Water Science and Engrg.; Dr. Warren E. Johnston, Dept. of Agricultural Economics; and Dr. Sy M. Gold, Dept. of Environmental Horticulture.
(d) Analytical-experimental combined with field work, Ph.D. thesis.
(e) Study the rates of infiltration and direction of flow from artificial recharge facilities, such as ponds, canals, trenches, and downwells with particular attention to testing the agreement between laboratory and field observations with current theories on unsaturated flow; determine the effects of various shapes, bank slopes, and geometric patterns of recharge facilities on ground water replenishment and economic efficiencies; and determine the design relationships of physical and economic efficiencies to aesthetic attractiveness and environmental usefulness of recharge facilities.

(7200)

TURBULENCE IN COMBINING MANIFOLDS.

- (c) Professor J. Amorocho.
(d) Theoretical and experimental; basic and applied research including doctoral thesis studies.
(e) Studies of the flow in converging manifolds, taking into account the mechanism of diffusion of turbulent flows. Laboratory studies involving the movement of turbulence, momentum and mass transfer, and energy dissipation in combining manifolds.
(g) Laboratory studies of energy and power losses of the mean flow in a pumping plant discharge manifold have been made. Power and energy transfer coefficients were measured for various branch intersection angles and junction geometries, and for various combinations of branch flows in the manifold.
(h) "Hydraulic Analysis of the A. D. Emonston Pumping Plant Manifold," J. J. DeVries, J. Amorocho, Water Science and Engineering Paper No. 1033, University of California, Davis, August 1969.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, School of Engineering and Applied Science, Department of Engineering, Los Angeles, California 90024. C. Starr, Dean, School of Engineering and Applied Science.

(5733)

INVESTIGATION OF TUNNEL DEPOSITS CAUSING OBSTRUCTION TO FLOW IN THE COLORADO RIVER AQUEDUCT SYSTEM.

- (b) University of California Water Resources Center, and the Metropolitan Water District of Southern California.
(c) A. F. Pillsbury, A. F. Sush, Andres Salla, Dept. of Engineering.
(d) Applied research.
(e) Research and investigation into the nature of deposits formed on the Colorado River Aqueduct tunnels has been performed and recommendations for control formulated.
(f) Terminated in 1968.
(h) Final report to be published.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, School of Engineering and Applied Science, Engineering Systems Department, Los Angeles, California 90024. Professor Moshe Rubinstein, Department Chairman.

(7201)

OPTIMIZATION OF WATER RESOURCES DEVELOPMENT: PHASE II.

- (b) University of California Water Resources Center and Office of Water Resources Research, USDI.
(c) Warren A. Hall and William W. Yeh.
(d) Basic and applied research.
(e) A comparative evaluation will be made of the use of "critical period hydrologies" to develop optimum operating policies as contrasted to more sophisticated but more expensive analytical procedures. The preceding project has used a critical period of seven dry years (1928-1934), and decisions on firm outputs have been based on this. This will be examined to evaluate the extent to which conclusions based on it depart from those using other methods. It will be evaluated first on simple systems and then later applied to large integrated systems.
(h) "Use of the Critical Period in Reservoir Analysis," W. A. Hall, A. J. Askew and W. W. Yeh, Water Resources Research 5(6), December 1969.
"An Alternate Procedure for the Optimization of Operations for Planning with Multiple-River, Multiple-Purpose Systems," W. A. Hall, G. W. Tauxe, and W. W. Yeh, Water Resources Research 5(6), December 1969.
"A Comparative Study of Critical Drought Simulation," A. J. Askew, W. W. Yeh, and W. A. Hall, presented at Natl. Fall Meeting of AGU, San Francisco, California, December 1969.
"Optimum Firm Power Output from a Two Reservoir System by Incremental Dynamic Programming," W. A. Hall, R. C. Harboe, W. W. Yeh and A. J. Askew, Water Resources Center Contribution 130, Univ. of California, Los Angeles, California, Oct. 1969.
"Scramflow Generating Techniques: A Comparison of their Abilities to Simulate Critical Periods of Drought," A. J. Askew, W. W. Yeh and W. A. Hall, Water Resources Center Contribution No. 131, January 1970.
"Optimal Planning and Operation of a Multiple-Purpose Reservoir System," W. W. Yeh, A. J. Askew and W. A. Hall, (in preparation).
"Use of Monte Carlo Techniques in the Design and Operation of a Multi-Purpose Reservoir System," A. J. Askew, W. W. Yeh and W. A. Hall (in preparation).

(7202)

OPTIMIZATION OF WATER RESOURCES DEVELOPMENT: PHASE III.

- (b) Office of Water Resources Research, USDI.
(c) William W. Yeh.
(d) Basic and applied research.
(e) The objective of the research is the application of operations research techniques to determine the best possible set of components for regional, complex, multipurpose water resources systems. In addition to many alternative schemes for development of regional or river basin water resources, there are many alternative capacity levels which could be specified as a master plan for regional development. Since zero capacity is equivalent to a negative decision with respect to any alternative component, the problem of optimization for regional or river basin planning purposes is equivalent to optimizing the capacities

specified for the basin or region master plan. The optimization is subject to the requirements of the many constraints that must be imposed, including the hydrological, economic, social, political, and legal constraints, as well as the usual physical limitations.

In addition, regional and river basin water plans will involve many specific objectives, some of which are not quantitative or readily relatable with equivalent economic accuracy, but may nonetheless be of critical importance. Any analytical model must permit reconciliation with the objectives if they cannot be explicitly incorporated.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, School of Engineering and Applied Science, Mechanics and Structures Department, Los Angeles, California 90024.
Professor Russell A. Westmann, Acting Department Chairman.

(7203)

BOUNDARY LAYER DEVELOPMENT IN STRATIFIED FLOWS.

- (b) National Science Foundation.
- (c) Dr. Robert E. Kelly and Dr. A. Charwat.
- (d) Theoretical, basic research; Ph.D. thesis.
- (e) Analysis of boundary development on a flat plate immersed in a stratified flow, for various values of Reynolds and Nusselt numbers ranging up to the onset of upstream growth of the boundary layer.
- (f) Completed.
- (g) Thermal diffusion can significantly affect the condition at which upstream growth occurs. Stratification tends to promote separation on cooled boundaries.
- (h) "Theoretical Analysis of Boundary Layer Regions in Stratified Flow," L. G. Redekopp, Ph.D. thesis, UCLA, 1969 (School of Engineering and Applied Science, Rep. 69-23).

(7204)

WAVE-INDUCED BOUNDARY LAYERS IN A STRATIFIED FLUID.

- (b) National Science Foundation.
- (c) Dr. Robert E. Kelly.
- (d) Theoretical, basic research; M.Sc. thesis.
- (e) Analysis of boundary layers induced by waves in a stratified fluid.
- (g) Induced mean motion due to a progressive thermal wave at a boundary has been investigated when the thermal wave resonates with a free oscillation. Such motion is stronger than in the non-resonant case. The secondary flow induced by standing waves has also been investigated. Possibility of separation is being investigated.
- (h) "Excitation of Gravity Waves and Production of Mean Currents in a Viscous, Stratified Fluid by a Temperature Wave on the Fluid Boundary," J. D. Vreeman, M.Sc. thesis, 1969.

(7205)

STABILITY OF STRATIFIED FLOWS.

- (b) National Science Foundation.
- (c) Dr. Robert E. Kelly.
- (e) Analysis of stability characteristics of stratified shear flows.
- (g) Stability boundaries and growth rates for the linear problem have been obtained as a function of Reynolds number. Theoretical analysis of the case when nonlinear effects predominate at the critical layer has been completed for small values of the Richardson number. Internal shear layers are formed.

(7206)

REPRESENTATION OF HOMOGENEOUS AND INHOMOGENEOUS TURBULENT FLOWS.

- (b) National Science Foundation.
- (c) Dr. William C. Meecham.
- (d) Theoretical, basic; Ph.D. thesis.
- (e) Investigation of turbulent flow processes whose statistical properties are close to Gaussian.
- (g) The Wiener-Hermite representation is being applied to various problems, with the refinement of utilizing a time-dependent base system. Application of this technique to the Burgers equation indicates considerable improvement in the effectiveness of the technique.

UNIVERSITY OF CALIFORNIA, LOS ANGELES, School of Engineering and Applied Science, Sonic Research Laboratory, Los Angeles, California 90024. C. Starr, Dean, School of Engineering and Applied Science.

(7207)

AZIMUTHAL DEPENDENCE OF SOUND BACKSCATTERED FROM THE SEA SURFACE.

- (b) Naval Undersea Research and Development Center.
- (c) Dr. Richard Stern, Assistant Professor.
- (d) Experimental, applied research, Master's thesis.
- (e) The dependence on azimuth angle of acoustic sea surface reverberation is investigated at 60 kHz utilizing a 3-axis rotationally stabilized conical beam transducer. Measurements of backscattering strength in the upwind and crosswind directions are compared for a range of grazing angles from 10 to 40 degrees.
- (f) Completed.
- (g) Data indicate that surface reverberation has a pronounced dependence on azimuthal angle at wind speeds below about 9 knots, but becomes independent of azimuthal angle at higher wind speeds.
- (h) "Azimuthal Dependence of Sound Backscattered from the Sea Surface," Jon Reeves, Lloyd Beck, Yoshira Igarashi and Richard Stern, J. Acoust. Soc. Amer., Vol. 46, No. 5, pp. 1284-1288, November 1969.

(7208)

OBSERVATION OF WIND WAVE GENERATED DOPPLER SHIFTS IN SURFACE REVERBERATION.

- (b) Naval Undersea Research and Development Center.
- (d) Experimental, applied research, Master's thesis.
- (e) Frequency shifts in surface reverberation were observed in the open sea as well as spectral broadening.
- (f) Completed.
- (g) Close correlation was seen between the shift in frequency and the wind generated waves. Possible explanations are offered for the spectral broadening.

UNIVERSITY OF CALIFORNIA, SAN DIEGO, Institute of Geophysics and Planetary Physics, La Jolla, California 92037. Dr. Walter Munk, Associate Institute Director.

(5927)

DEEP SEA TIDES.

- (b) Office of Naval Research.
- (c) Dr. Walter Munk and Mr. Frank Snodgrass.
- (d) Field investigation, theoretical analysis, basic research.
- (e) A self-recording instrument package is dropped freely to the sea bottom and records, *in situ*, pressure, temperature, and currents to a high de-

gree of precision. The instrument is acoustically recalled from a surface vessel, typically after one month.

- (g) On the basis of a number of stations off California, a part descriptive, part analytical description of deep sea tides for the northeast Pacific has been developed. Similar work is underway for the Antarctic.
- (h) "Deep-Sea Tides," W. H. Munk, Progress in Oceanography, Vol. 5, 67-69, 1969.
"Pelagic Tidal Measurements - A Suggested Procedure for Analysis," D. Cartwright, W. Munk, and B. Zetler, EOS, Vol. 50, No. 7, 472-477, 1969.
"A Rule of Thumb for Wave Breaking over Sloping Beaches," W. H. Munk and M. Wimbush, Oceanology, Vol. IX, No. 1, 71-75, 1969.
"Sensors in the Deep Sea," D. R. Caldwell, F. E. Snodgrass, and M. H. Wimbush, Physics Today, Vol. 22, No. 7, 34-42, 1969.
"Deep Sea Instrument Capsule," Frank Snodgrass, Science, Vol. 162, 78-87, 1968.

UNIVERSITY OF CALIFORNIA, SAN DIEGO, see also SCRIPPS INSTITUTE OF OCEANOGRAPHY.

CASE WESTERN RESERVE UNIVERSITY, Division of Fluid, Thermal and Aerospace Science, School of Engineering, Cleveland, Ohio 44106. Dr. Simon Ostrach, Division Head.

- (7209)
EFFECT OF SWIRL ON TWO-PHASE FLOW.
- (b) NASA.
- (d) Theoretical and experimental participation by students working for M.S. and Ph.D. degrees.
- (e) To obtain detailed understanding of how to maintain the liquid film on the inside of tubes as in once-through boilers. Experimentally either the gas core or liquid film or both can be made to swirl.
- (g) Swirl has been found to be beneficial in delaying the film break up.

- (7210)
THE STABILITY OF LAMINAR WATER BOUNDARY LAYERS ON A HEATED FLAT PLATE.
- (b) NASA - Lewis Research Center, Cleveland, Ohio.
- (c) Dr. Joseph M. Prah, Assistant Professor.
- (d) Experimental, basic research, one Ph.D., one M.S.
- (e) In a closed-loop water tunnel turbulence intensities of 0.01% will be attempted, so that an experimental stability curve for a laminar water boundary layer growing on a heated flat plate can be determined for various temperature differences. The viscosity's temperature dependence in water is expected to have a stabilizing effect as the temperature of the plate is raised above the free stream temperature.

- (7211)
THERMAL DISCHARGES.
- (c) Dr. Joseph M. Prah, Assistant Professor.
- (d) Experimental, basic research, one M.S.
- (e) The interaction of a warm, turbulent jet of water with a relatively cooler, quiescent basin of water is to be studied experimentally over a range of Froude numbers, density difference ratios, and geometries that are relevant to actual river entrance flows and cooling water return flows to large lakes and oceans. The project is to model these flows on a 20' x 6' water table.

(7212)
DYNAMICS OF EDGE TONE.

- (b) NASA.
- (c) Professor Isaac Greber.
- (d) Theoretical and experimental; participation by students working on M.S. and Ph.D. degrees.
- (e) Theoretical work directed toward explaining several aspects of edge tone oscillations. Experimental work directed primarily toward examining the manner in which edge tones are amplified by sound waves or nearby solid surfaces.
- (g) A simple theory has been formulated which describes the main features of the oscillations, based on the neutrally stable configuration of vortices over a surface. Explanatory experiments on amplified oscillations have been conducted. More detailed experiments are in progress.
- (h) Master's thesis "Vortex Model of the Edgetone," Thomas L. Labus, January 1970.

(7213)
LAMINAR FLOW FLUIDIC DEVICES.

- (b) Bell Laboratories and NASA.
- (c) Professor Isaac Greber.
- (d) Theoretical, experimental, design; participation by undergraduate and M.S. students.
- (e) Design of laminar flow fluidic devices based on calculated jet properties as influenced by geometry. Experiments to investigate performance of the designed devices.

(7214)
FLUID MECHANICS OF JETS.

- (b) NASA and Bell Laboratories.
- (c) Professor Isaac Greber.
- (d) Theoretical and experimental; participation by students working on M.S. and Ph.D. degrees.
- (e) Theoretical and directed toward examining effects of three-dimensionality, geometry and heat transfer on jet flows, and toward developing suitable calculational techniques. Experiments in planning stage.
- (g) Effects of surface curvature and heat transfer on laminar wall jets have been calculated. Effects of bounding sidewalls have been calculated for laminar jets whose unbounded analogies are free jets and wall jets. New calculational schemes are being devised.
- (h) "Similarity Solution for a Laminar, Incompressible Jet Flowing Along a Curved Surface," Bruce Lindow and Isaac Greber, AIAA, J., Vol. 6, No. 7, pp. 1331-1335, July 1968.
"Linearized Analysis of Flow of Incompressible Laminar Jet Contained Between Side Walls," Isaac Greber and Sashi Singhania, ASME 69-FLCS-30, June 1969.

(7215)
THE COASTAL BOUNDARY LAYERS IN A LAKE.

- (b) NASA.
- (c) Professor Gerald S. Janowitz.
- (d) Theoretical investigation; basic research.
- (e) An investigation of the nature of the linear hydrostatic boundary layers in which the horizontal motion is brought to rest at the shores of a lake of uniform depth containing a homogeneous fluid undergoing a quasi-steady turbulent motion characterized by constant, though vastly differing horizontal and vertical eddy diffusivities.
- (g) It is found that the flow near the shore is determined by the local wind stress and the local value of the interior velocity parallel to the coast. Under certain wind stress conditions there is a regional flow adjacent to the coast in which the fluid is effectively confined to the coast.

- (7216)
 JETS IN CROSS-FLOW.
 (b) NASA.
 (c) H. K. Wiskind, Associate Professor.
 (d) Experimental applied research, doctoral dissertation.
 (e) Measurements are underway and being planned to collect data on trajectory and spread of jets of different shapes and flow conditions in a cross-flow. Thermal mixing is also being investigated. We are looking for the best manner to correlate the measurements. It is hoped this information will be useful for turbine combustor designers and in other technical problems.
 (g) Beginning measurements in a small and large wind tunnel with a 4-inch round jet from a carefully machined nozzle have been made. The effect of density variation has been investigated by heating the jet to as much as two times the ambient absolute temperature.

(7217)
 TURBULENT MIXING OF GASES.

- (b) NSF, NASA.
 (c) H. K. Wiskind, Associate Professor.
 (d) Experimental, basic, Master's and doctoral research.
 (e) This project was initiated to make measurements that would yield information on the fine scale structure of the turbulent mixing of gases. To date, hot-wire spectral measurements of turbulence have been made in a large jet flow and three sets of measurements downstream of a grid-injection device which produces nearly homogeneous turbulence with mixing. The purpose of this work is to provide empirical data to compare with published theories of the universal characteristics of fine scale turbulent gas mixing.
 (g) Results have been obtained on the mixing of helium into air and on air into air with and without a temperature difference. These measurements, although limited, show some agreement of applicable published predictive calculations.
 (h) "The Measurement of Concentration Fluctuations in the Mixing of Two Gases by Hot Wire Anemometer Techniques," W. L. Conger.
 "Measurements of Turbulent Energy Spectra," Master's thesis, University of Pennsylvania, May 1966, H. L. Duane.
 "Measurements of the Convective Heat Transfer to Air and Air-Helium Mixtures from Heated Wires," Master's thesis, University of Pennsylvania, June 1966, L. Dadone.
 "Some Effects of Air Injection on the Turbulence Generated by a Bi-Planar Grid," FTAS/TR69 Case Western Reserve University, June 1969, D. Luxenburg and H. K. Wiskind.
 "Experiments on the Turbulent Gas Mixing of Momentum, Heat and Mass Downstream of a Grid-Injection Device," H. K. Wiskind, W. Conger, E. Hopfinger and D. Luxenburg, (Abstract in Bulletin Amer. Physical Soc., 14, 11, 1105, 1969).

THE CATHOLIC UNIVERSITY OF AMERICA, Department of Civil Engineering, Washington, D. C. 20017. Dr. Reis S. Heller, Jr., Acting Department Chairman.

- (3031)
 HYDROLOGY OF GREAT LAKES - ST. LAWRENCE RIVER BASIN.
 (c) Dr. B.S. Browzin, Prof. of Civil Engrg. and Mech.
 (d) Basic research.
 (e) Research is based on long range flow and meteorologic records. Flow and precipitation data on U.S. and Canada stations were statistically inves-

- tigated in order to establish basic long-range hydrologic characteristics of the basin.
 (g) Water balance for four basins was calculated; paper is in preparation for submission at the Symposium on World Water Balance, Reading, England.
 (h) "Monthly Water Balances in Tributary Watersheds of the Great Lakes-St. Lawrence Basin as Influenced by Climatic Factors." In preparation.
 "Données Fondamentales sur l'hydrologie des zivrières dans le Bassin du Saint-Laurent," Univ. of Grenoble.
 (7226)
 TRANSIENT FLOW IN POROUS MEDIA.
 (c) Dr. B.S. Browzin, Prof. of Civil Engrg. and Mech.
 (d) Basic research; theoretical.
 (e) Hele-Shaw flume research for verification of approximations assumed in analytical solutions.
 (g) (1) Solution is obtained for transient flow through earth slopes; (2) new principle developed for analytical solution of flow to drains with possible application to other boundary conditions (publication in preparation).
 (h) "Transient Flow Through Earth Slopes," 13th Congr. Intl. Assoc. Hyd. Res., Kyoto, Japan, Sept. 6-11, 1969. Post-Congress Volume, Vol. 5-2.

THE CATHOLIC UNIVERSITY OF AMERICA, Department of Space Science and Applied Physics, Washington, D. C. 20017. Dr. C. C. Chang, Department Head.

- (6448)
 HYDRODYNAMICS OF LIQUID-LIQUID INTERFACE.
 (b) National Science Foundation.
 (c) Associate Professor Timothy W. Kao.
 (d) Experimental and theoretical basic research; M.S. and Ph.D. theses.
 (e) Stability and mixing of two liquids in parallel shear flow.
 (f) First stage completed; continuing.
 (g) The stability of oil and water interface is found to be a manifestation of the instability in the water phase.
 (h) "Role of the Interface in the Stability of Stratified Flow Down an Incline Place," Timothy W. Kao, Phys. of Fluids, 8, 2190-2194, Dec. 1965.
 "Stability of Gravity-Motivated Plane Poiseuille Flow of Two Fluids," Timothy W. Kao and C. Park, Proc. 10th Midwestern Mechanics Conf., Ft. Collins, Colorado, Aug. 1967.
 "Measurements of Mean Flow Profiles and Stability of the Co-Current Flow of Two Immiscible Liquids," Timothy W. Kao and C. Park, Tech Rep. 67-032, Dept. of Space Science and Appl. Physics, The Catholic Univ. of Amer., Washington, D. C., Nov. 1967.
 "Role of Viscosity Stratification in the Stability of Two-Layer Flow Down an Incline," Tech. Rept. 67-031, Dept. of Space Science and Appl. Physics, The Catholic Univ. of Amer., Washington, D. C., Nov. 1967.

- (6449)
 EXPERIMENTAL STUDY OF A WEAK TURBULENT FIELD.
 (b) National Aeronautics and Space Administration.
 (c) Professor S. C. Ling.
 (d) Experimental basic research; Ph.D. thesis.
 (e) To study decay of turbulence created behind a grid.

- (6450)
 FREE SURFACE PLANNING.
 (b) National Science Foundation.
 (c) Paul Rispin, Assistant Professor.
 (d) Theoretical basic research.
 (e) Nonlinear free surface problem.
 (g) Singular perturbation method is applicable.

- (6451)
 DYNAMICS OF ATMOSPHERIC VORTICES.
 (b) National Science Foundation.
 (d) Experimental and theoretical basic and applied research; M.S. and Ph.D. thesis.
 (e) Vortex motion over a fixed flat boundary.
 (g) Measurement of turbulent boundary layer flow created by a vortex over a fixed flat plate. Numerical studies.
 (h) "A Numerical Computation of a Confined Vortex," H. P. Pao, Tech Rep. 67-024, Dept. of Space Science and Appl. Physics, The Catholic Univ. of Amer., Washington, D. C., April 1967.
 "On the Stability of a Revolving Conducting Fluid in a Circular Magnetic Field," Proc. 10th Midwestern Mechanics Conf., Ft. Collins, Colorado, August 1967.
 "Sources and Sinks at the Axis of a Viscous Rotating Fluid," H. P. Pao and T. W. Kao, Tech. Rep. 66-012, Dept. of Space Science and Applied Physics, The Catholic University of America, Washington, D. C., July 1966.

UNIVERSITY OF CINCINNATI, Department of Chemical and Nuclear Engineering, Cincinnati, Ohio 45221. James H. Leonard, Department Head.

- (6138)
 BLOOD FLOW PROPERTIES.
 (c) Dr. Daniel Hershey.
 (d) Experimental and theoretical; basic and applied research; M.S. and Ph.D. theses.
 (e) Steady and pulsatile flow properties of blood in rigid and distensible tubes.
 (h) "Friction Factors and Pressure Drop for Sinusoidal Laminar Flow of Water and Blood in Rigid Tubes," A.I.Ch.E. Jour., 13, 491-6 (1967).
 "Analytical and Experimental Description of Blood Flow," Digest of 7th Int. Conf. on Med. and Biol. Eng., 374, Stockholm, 1967.

- (7227)
 BOILING AND TWO-PHASE FLOW STUDIES.
 (c) Dr. Joel Weisman.
 (d) Experimental and theoretical, basic and applied research, M.S. and Ph.D. theses.
 (e) Study of the flow properties of vapor-liquid mixtures and boiling under transient conditions. Application to water cooled nuclear power reactors.

- (7228)
 FOAM DRAINAGE AND OVERFLOW.
 (b) Federal Water Pollution Control Administration.
 (c) Dr. Robert Lemlich.
 (d) Experimental and theoretical, basic and applied research, Ph.D. theses.
 (e) The behavior of liquid foam with regard to its coalescence, interstitial drainage, liquid content, and bulk flow. Applications to foam fractionation, drainage, and flow.
 (h) "Foam Fractionation," R. Lemlich, Chem. Eng. 75: No. 27, 95-102 (1968).
 "Adsorptive Bubble Separation Methods," R. Lemlich, Ind. Eng. Chem. 60: No. 10, 16-29 (1968).

- "Principles of Foam Fractionation," R. Lemlich, Chapt. 1 in Progress in Separation and Purification, Vol. 1, 1-56, E. S. Perry, Editor, Interscience, New York (1968).
 "A Study of Interstitial Liquid Flow in Foam. Part III: Test of Theory," F. S. Shih and R. Lemlich, AIChE Jour. 13:751-754 (1967).
 "Predicting the Performance of Foam Fractionation Columns," S. Fanlo and R. Lemlich, A.I.Ch.E.-I. Chem.E. Symposium Series No. 9, 75-78, 85-86 (1965).
 "A Study of Interstitial Liquid Flow in Foam. Part I: Theoretical Model, and Application to Foam Fractionation," R. A. Leonard and R. Lemlich, A.I.Ch.E. Jour., 11:18-25 (1965).
 "A Study of Interstitial Liquid Flow in Foam. Part II: Experimental Verification and Observations," R. A. Leonard and R. Lemlich, A.I.Ch.E. Jour., 11:25-29 (1965).

UNIVERSITY OF CINCINNATI, Department of Civil Engineering, Hydraulic Laboratory, Cincinnati, Ohio 45221. Dr. L. M. Laushey, Head, Civil Engineering Department, Dr. H. C. Preul, Directing Head, Hydraulic Laboratory.

- (6461)
 AERATION THROUGH HYDRAULIC STRUCTURES.
 (b) Ohio River Division, Corps of Engineers.
 (c) Dr. Herbert C. Preul.
 (d) Experimental; applied research; laboratory and field measurements.
 (e) Study of reaeration of rivers at gated structures. Oxygen uptake is measured with different discharges, gate openings, and submergences. Purpose is to determine optimum operation of gates to maximize reaeration.
 (6462)
 UNSTEADY FLOW.
 (c) Dr. Louis M. Laushey.
 (d) Experimental and theoretical; laboratory measurements; for doctoral dissertation.
 (e) Measurements in ground water tank and Hele-Shaw apparatus to confirm equations for unsteady flow and to determine the friction during unsteady flow.
 (h) Progress report published in the Proc., Symp. of the IASH, Bern, Switzerland, October 1967.

- (6463)
 TRAVEL OF POLLUTANTS IN AQUIFERS.
 (b) U.S. Public Health Service.
 (c) Dr. Herbert C. Preul.
 (d) Experimental; laboratory and field.
 (e) Measurements of amount of contamination and travel velocity of contaminants in ground water.

- (6464)
 MODEL OF RIVER BASIN.
 (b) Southwestern Ohio Water Company.
 (c) Dr. Louis M. Laushey and Mr. Robert C. Lewis.
 (d) Experimental and theoretical.
 (e) Construction of an electrical analogy, a computer solution, and a mathematical model for an aquifer in the Miami River Basin. Objective is to develop criteria and methods for the optimum management of the aquifer.
 (h) Progress report published as Paper A54, Proc. 13th Congr. IAHR (Kyoto), Aug-Sept. 1969.

- (7229)
URBAN RUNOFF CHARACTERISTICS.
(b) Federal Water Pollution Control Administration.
(c) Dr. Herbert C. Preul.
(d) Experimental and theoretical; field and laboratory measurements - largely field oriented.
(e) Ultimate objective is to develop mathematical model for urban runoff characteristics. Data being collected relating to quantity and quality of various sources of pollution within a combined sewer drainage area in Cincinnati, Ohio.

CLARKSON COLLEGE OF TECHNOLOGY, Department of Mechanical Engineering, Potsdam, New York 13676. George Leppert, Department Chairman.

- (7230)
INSTABILITY OF A LIQUID LAYER.
(c) Dr. S. P. Lin.
(d) Theoretical; for Ph.D. thesis.
(e) To predict the onset and the development of the instability in a liquid layer.
(g) Subcritical finite amplitude instability is shown to be impossible and supercritically stable wave regimes are found. Effects of surface-active agents on film stability is found to be very profound.
(h) J. Fluid Mech. 36, 1969 and 40, 1970.

CLEMSON UNIVERSITY, College of Engineering, Department of Mechanical Engineering, Cook Engineering Laboratory, Clemson, South Carolina 29631. Department Chairman, Professor C. K. Johnson.

- (7231)
VERIFICATION OF TWO-DIMENSIONAL SHORT DIFFUSER DESIGN METHOD.
(b) Lewis Research Center, NASA.
(c) Dr. T. T. Yang.
(d) Experimental and theoretical; applied research relates to doctoral theses.
(e) A computer aided method of design of plane flow short unseparated diffusers by incompressible theory developed by the correspondent while he was a Faculty Fellow at Lewis Research Center is being experimentally verified. The method has possible application to gas turbine diffusers. The test program consists of testing a quarter circle diffuser with 4:1 area ratio with slot suction at varying location and a specially contoured diffuser with 4:1 area ratio which gives better control over the wall pressure gradient. A method of analytical design of specially contoured axially symmetric diffusers is also being developed.

- (7232)
COMPRESSOR INTAKE INTERFERENCE OF A MULTIPLE GAS TURBINE SYSTEM.
(b) General Electric Gas Turbine Plant, Greenville, South Carolina.
(c) Dr. T. T. Yang and Dr. E. F. Cox.
(d) Experimental; applied research.
(e) An experimental program to investigate the re-ingestion of hot exhaust gases from gas turbines was performed. The tests were conducted on a 4' x 12' x 3-1/2" deep water table using a 223:1 scale model. Tests performed with and without cross wind indicated no direct flow path from the exhaust to the intake but rather a general overall contamination of the environment which even-

tually resulted in an increase in temperature at the turbine inlet.

- A second phase test program was recommended which would use hot air to simulate the exhaust gas and would provide both dynamic and geometric similarity of the full scale unit. Provisions would also be available for determining the overall effects of five units operating simultaneously with and without cross wind. Modifications to this test system will be made to improve performance. Recommendations will be made for improving performance of the full scale unit.
(g) The test results showed no evidence of direct injection of discharge gas or hot air into the intakes but rather that the intake temperature rise was a result of the environment contamination. The ground wind in the direction parallel to the gas turbine base and parallel to the longitudinal axis had a favorable effect on preventing an increase of the intake air temperature. However, at high wind speed or at a different wind direction the result may be quite different.

- (7233)
IMPROVED CONVECTIVE HEAT TRANSFER ENHANCEMENT BY THE PAIRED SPACING OF SURFACE ROUGHNESSES.
(c) Dr. C. A. Brandon and Dr. A. C. Elrod.
(d) Experimental; applied research.
(e) Uniformly-spaced, transverse-rib surface roughnesses are widely used to enhance forced convection heat transfer. The optimum rib heights for some narrow channel applications are often in the order of 0.001 inch and thus are difficult to manufacture. An experimental study of the enhancement and pressure drop characteristics of large, nonuniformly-spaced ribs is in progress. The large ribs studied have been rubber bands stretched on a copper rod. The flow channel is the annular space between the copper rod and the internal diameter of a pipe. The transient cooling of the copper rod has been used to determine the convective enhancement over the Reynolds number range of 5000 to 30,000.

- (7234)
THE EFFECT OF SUSPENDED PARTICLES ON TURBULENT FLOW IN A PIPE.
(b) National Science Foundation.
(c) Dr. C. A. Brandon.
(d) Experimental and theoretical; applied research.
(e) This research will measure and compare turbulent energy spectra obtained with and without suspended particles in the central region of an air flow in a 2-inch pipe. A laser-doppler anemometer which requires no physical probe in the flow will be used to make Eulerian measurements for both the homogeneous and the suspension flows. Comparison of the spectra will provide experimental quantification of the effects of large particles on the fluid turbulence.

- (7235)
A TEST OF A SIMILARITY VARIABLE FOR DILUTE FLUID SOLID SUSPENSION HEAT TRANSFER.
(c) Dr. C. A. Brandon.
(d) Experimental; applied research relates to M.S. thesis.
(e) Air suspensions of three sizes of glass microspheres (50 μ m, 70 μ m, and 100 μ m) were studied in vertical upward flow in 1-inch and 2-inch test sections. The pipe Reynolds number, based on air properties alone, was varied 20,000 to 75,000. The enhancement in the convective heat transfer to the suspensions and the increased static pres-

sure drop were measured. The objective of the work was to test the proposed similarity variable,

$$\frac{\text{particle size}}{\text{microscale of turbulence}} = (d_p/D) \text{Re}^{11/16},$$

where D is pipe diameter.

- (g) Verified the product, $(d_p/D) \text{Re}^{11/16}$, as a similarity variable and confirmed peak enhancement for a constant value of the product; $(d_p/D) \text{Re}^{11/16} = 1.8$.

COLORADO SCHOOL OF MINES, Basic Engineering Department, Golden, Colorado 80401. Dr. David T. Snow.

(7236)

TRANSPORTATION OF SOLID-LIQUID MIXTURES IN PIPELINES.

- (c) Professor R. R. Faddick, Multiphase Flow Laboratory.

- (e) Facilities have recently been provided for the study of the transportation of mixtures of liquids and solids in pipelines. Studies will center around friction losses, mixing in tanks, instrumentation, injection devices, and rheology of mixtures. Current studies include mixing theory, elbow flowmeter studies, and rheology of mineral slurries.

(7237)

STRUCTURE OF SCALAR FIELDS MIXED BY TURBULENCE FOR ARBITRARY SCHMIDT NUMBERS.

- (b) National Science Foundation.

- (c) Dr. D. M. Kesic.

- (e) The structure of scalar fields convected by turbulence in incompressible turbulent flows is investigated through solutions of corresponding spectrum equations. A vorticity approximation concept enables a solution for the stationary spectrum scalar function to be obtained in closed form. The solution, valid for arbitrary Schmidt numbers, covers the entire universal equilibrium range and produces the asymptotic k^{-1} and $k^{-17/3}$ regions for $Sc \rightarrow \infty$ and $Sc \rightarrow 0$, respectively, for corresponding ranges of wave numbers. A water pipe flow system, with an injected dye solution, will be used for investigation of mixing systems with $Sc \gg 1$.

- (g) "Spectra of Turbulent Energy and Scalar Fields in Isotropic and Shear Turbulence," D. M. Kesic, Ph.D. thesis, Colorado State University, Fort Collins, 1969.

(7238)

DISPERSION OF RADIONUCLIDES TRANSPORTED BY GROUND-WATER FLOWING IN FRACTURED MEDIA.

- (b) Isotopes, Inc., Palo Alto, California.

- (d) Theoretical and experimental, basic and applied.

- (e) Digital simulation is used to reproduce the complex paths of a dilute solute that originates at a random point in systematic networks of intersecting conduits. At all fracture intersections, the solute is diluted or split. At various times, the dispersion cloud is arrested and dispersivities determined. Numerous models are analyzed to show the heterogeneity of dispersion properties characteristic of real fractured basement rock. Field methods are developing for measuring the parameters of real rocks governing dispersivity, preliminary to the task of evaluating safety of underground nuclear detonations.

- (g) The dispersion tension has been deduced for random cubic systems for hydraulic gradients at a variety of orientations with respect to the system coordinates.

- (h) The following publications were authored by

David T. Snow:

"A Parallel-Plate Model for Permeable Fractured Media," Ph.D. thesis, University of California, Berkeley, 1965.

"Estimation of Fracture Porosity in Crystalline Rock," Chemical Grouting Topics No. 5, American Cyanamid Co., Wayne, N. J., 9 pp., 2 figs., 1965 (with R. H. Karol).

"Grouting," in Annotated Bibliography on Selected Mining Methods, Quart., Colo. School of Mines, Vol. 61, No. 2, p. 128-139, 1966 (with G. Bator).

"Three-Hole Pressure Test for Anisotropic Foundation Permeability, Felsmechanik und Ingenieur-Geologie, Vol. IV, No. 4, p. 288-315, 1966.

Discussion: Proc. 1st Intl. Cong. on Rock Mech., Lisbon, Vol. 3, p. 243-244, 1967.

"Hydraulic Character of Fractured Metamorphic Rocks of the Front Range and Implications to the Rock Mountain Arsenal Well," Quart., Colo. School of Mines, 1968, Vol. 63, No. 1, p. 167-199.

"Fracture Deformation and Changes of Permeability and Storage Upon Changes of Fluid Pressure," Quart., Colo. School of Mines, 1968, Vol. 63, No. 1, pp. 201-244.

"Rock Fracture Spacings, Openings and Porosities," J. Soil Mech. & Found. Div., ASCE, Vol. 94, No. 1, pp. 73-91, 1968.

"Closure to Discussions, Rock Fracture Spacings, Openings and Porosities," J. Soil Mech. & Found. Div., ASCE, Vol. 95, No. 3, pp. 880-883, 1969.

Discussion of "Transmissibility as Function of Scale," Proc. Nat. Symp. on the Analysis of Water-Resource Systems, Amer. Water Res. Assoc., Denver, 1968, p. 141.

"Permeability of Crystalline Rock Interpreted from Measured Orientations and Apertures of Fractures," (with L. Bianchi) Annals of Arid Zone, Jodhpur, India, Vol. 8, No. 2, 1969.

"Anisotropic Permeability of Fractured Media," Water Resources Research, 1969, Vol. 5, No. 6, pp. 1273-1289.

"The Frequency and Apertures of Fractures in Rock," Intl. Jour. Rock Mech. & Mining Sci., 1970, Vol. 7, pp. 23-40.

COLORADO STATE UNIVERSITY, ENGINEERING RESEARCH CENTER, College of Engineering, Foothills Campus, Fort Collins, Colorado 80521. Dr. D. B. Simons, Associate Dean, Engineering Research Center.

(096W)

GRAND VALLEY SALINITY CONTROL DEMONSTRATION PROJECT.

- (c) G. V. Skogerboe, Agric. Engrg. Department.

To be published in Water Resources Research Catalog in the near future.

(097W)

HYDRAULICS OF SURFACE IRRIGATION.

Reported in Water Resources Research Catalog, Vol. 4, 2.0215.

(098W)

HYDRAULIC OPERATING CHARACTERISTICS OF LOW GRADIENT BORDER IRRIGATION SYSTEMS.

Water Resources Research Catalog, Vol. 4, 3.0139.

(099W)

IMPROVEMENTS IN MOVING SPRINKLER IRRIGATION SYSTEMS FOR CONSERVATION OF WATER.

- (c) Office of Water Resources Research.

- (c) D. L. Miles, Agric. Engrg. Department.

See WRRRC for details.

- (100W)
HYDROLOGIC SUITABILITY OF DRAINAGE BASINS FOR PRECIPITATION MODIFICATION AND STATISTICAL EVALUATION OF RESULTS.
See WRRC for details.
- (101W)
MULTIVARIATE ANALYSIS OF SMALL WATERSHED RAINFALL-RUNOFF RELATIONS.
See WRRC for details.
- (1789)
COMPUTER PROGRAM - APPLICATION TO STOCHASTIC HYDROLOGY.
(b) U. S. Bureau of Reclamation.
(c) V. Yevjevich, Professor of Civil Engineering.
(d) A computer program is being developed for structural analysis of available samples, and simulation of large samples by the Monte Carlo method for daily river flows.
(f) The program is close to final form.
- (2885)
HYDROLOGIC STOCHASTIC PROCESS.
(See also Nos. 2812 and 2846 in past issues of HRUS.)
(b) National Science Foundation.
(c) Dr. V. Yevjevich, Professor of Civil Engineering.
(d) Theoretical, basic research.
(e) The studies relate to the stochastic structure of hydrologic time series. Annual, monthly and daily rainfall and runoff data have been studied.
(g) Several new statistical methods have been applied to hydrologic time series studies.
(h) "Mean Range of Linearly Dependent Normal Variables with Application to Storage Problems," Vujica Yevjevich, Water Resources Res., Vol. 3, No. 3, Third Quarter 1967, pages 663-671.
"The Investigation of Relationship Between Hydrologic Time Series and Sunspot Numbers," Ignacio Rodriguez-Iturbe and Vujica Yevjevich, Colorado State University Hydrology Paper No. 26, Apr. 1968.
"Mathematical Formulation of a General Stochastic Sediment Transport Model," P. Todorovic and H. W. Shen, submitted in October 1968 for publication in J. Fluid Mechanics.
"Effects of Truncation on Dependence in Hydrological Time Series," Rezaul Karim Bhuiya and Vujica Yevjevich, Colorado State University Hydrology Paper No. 31, November 1968.
"Extreme Values of Precipitation Phenomena," P. Todorovic and Emir Zelenhasic, Bull. Intl. Assoc. Scientific Hydrology, XIII, December 1968.
"Properties of Non-Homogeneous Hydrologic Series," V. Yevjevich and R. I. Jeng, April 1969, Colorado State University Hydrology Paper No. 32.
"Runs of Precipitation Series," Jose Llamas and M. M. Siddiqui, May 1969, Colorado State University Hydrology Paper No. 33.
"Stochastic Process of Precipitation," P. Todorovic and V. Yevjevich, September 1969, Colorado State University Hydrology Paper No. 35.
- (2911)
LARGE CONTINENTAL DROUGHTS.
(b) National Science Foundation.
(c) V. Yevjevich, Professor of Civil Engineering.
(d) Theoretical; basic and applied research.
(e) The purpose of this study is to investigate the physical predictability of droughts, probabilistic properties of droughts of given duration, deficit and areal coverage, and engineering and economic aspects of droughts.
(g) Initiated in September 1969.
- (5164)
FLOW MEASUREMENT.
(b) Colorado Agric. Expt. Sta., Civil Engrg. Sect., and Northern Plains Soil and Water Conservation Research Div., ARS, U. S. Dept. of Agriculture.
(c) Dr. H. J. Koloseus, Professor of Civil Engineering.
(d) Experimental laboratory and basic research which involves staff and graduate student participation leading to M.S. and Ph.D. degrees.
(e) This project has the general objectives of developing and improving devices and techniques for the conduction and measurement of irrigation water. At present, the response of stilling wells to pressure fluctuations is being studied.
(g) The circular hydraulic jump has been studied analytically and experimentally. The analytical work indicated that the sequent depth and the head loss for the circular jump are greater than that for the rectangular jump. Experiments tended to confirm these findings; they also tended to indicate that the length of the circular jump is less than that of the rectangular jump.
(h) "Circular Hydraulic Jump," H. J. Koloseus and D. Ahmad, J. Hydr. Div., ASCE, Vol. 95, No. HY1, Jan. 1969, pp. 409-422.
- (5607)
EVALUATION OF DEPENDENT AND INDEPENDENT VARIABLES IN OPEN CHANNEL FLOW.
See U. S. GEOLOGICAL SURVEY.
- (5610)
MECHANICS OF FLOW STRUCTURE AND FLUID RESISTANCE - MOVABLE BOUNDARY.
See U. S. GEOLOGICAL SURVEY.
- (6071)
REAERATION IN OPEN CHANNEL FLOW.
See U. S. GEOLOGICAL SURVEY.
- (7239)
ATMOSPHERIC WATER.
(b) State of Colorado (used partially as matching funds for OWRR project).
(c) Dr. J. Rasmussen, Department of Atmospheric Science.
(d) Experimental research; applied research.
(e) Study of the atmospheric water balance (1) in cyclones, (2) over river basins. Purpose is to (a) model the evaporation, condensation, precipitation cycle in large extratropical cyclones and relate this to ground responses, e.g., hydrologic phenomena; (b) to use the atmospheric water balance as a computation technique to obtain winter season precipitations minus evaporation over the upper Colorado River and relate this to annual runoff. The benefit of this research would be a forecast equation $P - E = f(\text{runoff})$.
(g) An analysis technique for the study of the atmospheric water balance of cyclones has been finished and published.
(h) "Moisture Analysis of an Extratropical Cyclone," J. Rasmussen, R. W. Furman, H. Riehl, Archive for Meteorology, Geophysics and Bioclimatology, Series A, 18, 275-298, 1969.
"A Case Study of the Precipitation Distribution in a Cyclone," D. Hadley, M.S. thesis, Dept. of Atmospheric Science, Colorado State University (in publication, 1970).
"The Atmospheric Water Balance and Hydrology of Large River Basins," J. Rasmussen, Proc. 5th American Water Resources Conference, San Antonio, Texas, November 1969.

- (7240)
SIMILITUDE FOR FLOW OF TWO FLUIDS IN POROUS MEDIA.
(b) National Science Foundation.
(c) A. T. Corey, Department of Agricultural Engrg.
(d) Experimental and theoretical research.
(e) A study to determine the extent variations in soil air pressure might affect flow of water in soils, particularly flow associated with infiltration, and to examine a theory for modeling simultaneous flow of air and water.
- (g) It has been found that air-pressure gradients can be built up during infiltration which significantly affect the rate of infiltration. Air pressure build-up due to infiltration can often disturb the upper portion of soil during rapid air escape. The magnitude of air pressure build-up depends on properties of the soil and the rate of water application at the surface.
- (7241)
IMPROVEMENTS IN MOVING SPRINKLER IRRIGATION SYSTEMS FOR CONSERVATION OF WATER.
(b) Colorado State University Agricultural Experiment Station.
(c) D. L. Miles, Agricultural Engineering Department.
(d) Experimental and theoretical; applied and basic research, development.
(e) The purpose of this project is to investigate the affect of time-varying water application rates on infiltration rates under moving sprinkler systems and to incorporate these findings into mathematical models of moving sprinkler irrigation systems to modify design and operation for improved performance. Present systems apply water in such a manner that it cannot be absorbed uniformly by most soils. Application rates exceed infiltration rates over a large portion of the irrigated area, resulting in water collecting in low spots. This research will evaluate the infiltration process in the unique conditions found under moving systems and will use the findings to modify equipment to better match application rates to intake rates.
- (5892)
FLOW INTO SUB-SOIL DRAINS.
(b) Colo. State Univ. Agric. Exp. Station and Agric. Research Service, U.S. Dept. Agric.
(c) A. T. Corey, Dept. of Agric. Engrg. and H. R. Duke, ARS, USDA.
(d) Experimental theoretical, applied research and development.
(e) Techniques for modeling systems involving drainage from soils are being used to evaluate present criteria for the design of subsoil drains. Both physical and mathematical models are being investigated. Purpose is to develop improved design criteria and in particular, to develop criteria that will take into account flow in the partially saturated region above the water table.
(g) A theory of similitude, applicable for models involving drainage from soils, was developed. The models (physical and mathematical) were employed to evaluate the importance (to drainage design calculations) of accounting for flow above the water table. It was shown that satisfactory results cannot be obtained by ignoring this flow. It was also shown that to describe the drainage process mathematically it is necessary to determine the pore-size distribution of the soil.
- (h) "Properties of Porous Media Affecting Fluid Flow," R. H. Brooks and A. T. Corey, J. Irrig. and Drainage Div., Proc. ASCE, Vol. 92, No. IR2, June 1966, pp. 61-88.
"Hydraulic Properties of Disturbed and Undisturbed Soils," G. E. Laliberte and A. T. Corey, Special Tech. Publ. No. 417, ASTM, 1967, pp. 56-71.
"Similitude for Drainage of Soils," G. L. Corey and A. T. Corey, J. Irrig. and Drainage Div., Proc. ASCE, Vol. 93, No. IR3, Sept. 1967, pp. 3-23.
"Permeability Calculated from Desaturation Data," G. E. Laliberte, R. H. Brooks, and A. T. Corey, J. Irrig. and Drainage Div., Proc. ASCE, Vol. 94, No. IRL, March 1968, pp. 57-71.
- (55)
SNOW COURSE MEASUREMENTS AND FORECAST ANALYSIS.
(b) Soil Conservation Service; Colorado Agricultural Experiment Station.
(c) J. N. Washichek, Snow Survey Supervisor, Agric. Engrg. Section.
(d) Field investigations; applied research.
(e) Systematic measurements of depth and water content of snow are being made at high elevations in Colorado and New Mexico mountain areas for the purpose of forecasting the runoff of the principal rivers in the interest of irrigation, power, domestic supplies and other uses. Development of remote sensors to provide day by day snow pack analysis. This would provide considerable more data for forecasting as well as evaluation of atmospheric projects and flood potential.
(g) Forecasts are now being issued at forty-four gaging stations in Colorado and New Mexico. As forecast procedures improve, additional streams will be forecasted and other areas of potential power and irrigation development will be investigated on the Colorado, San Juan, Animas and Arkansas Rivers.
(h) Colorado Agricultural Experiment Station General Series Papers Nos. 879, 880, 881, 882 covering monthly snow reports for all of Colorado and New Mexico. Nine small basin reports and one two-state bulletin covering the South Platte River watershed; Arkansas River watershed; Rio Grande watershed in Colorado; Rio Grande watershed in New Mexico; Dolores River watershed; San Juan and Animas River watershed; Gunnison River watershed; Colorado River watershed; Yampa, White and North Platte River watershed; Lower South Platte River watershed. Supplemental reports are issued January 1, May 15, and June 1. Progress reports on the Steamboat Springs Project, San Juan Project in Colorado and Jemez Mountain Project in New Mexico.
- (7244)
DETERMINATIONS OF WIND DRAG FORCE COEFFICIENTS FOR ELEVATED OCEAN STRUCTURES.
(b) National Science Foundation and Chevron Oil Field Research Corporation.
(c) J. H. Nath, Dept. of Civil Engrg.
(d) Applied research, experimental.
(e) Wind drag coefficients are determined for elevated structures. The Colorado State University wind tunnel is being utilized for the experimental work.
(g) Tentative results show that drag coefficients are lower for elevated structures than for bottom based structures.
- (7245)
DYNAMIC RESPONSE OF MOORED BUOY SYSTEMS IN DEEP WATER.
(b) Office of Naval Research.
(c) J. H. Nath, Dept. of Civil Engrg.
(d) Applied and theoretical research.
(e) A numerical model of the response of a one-point mooring to ocean waves in deep water was developed. It is intended to investigate the influence of

- water depth, line type, and scope on the response.
- (g) The numerical model is completed and experimentation with it is about to start.

(7246)

A SYSTEMATIC TREATMENT OF THE PROBLEM OF INFILTRATION.

- (b) U.S. Dept. of Interior, Office of Water Resources Research.

- (c) H. J. Morel-Seytoux, Assoc. Prof. of Civil Engrg.
- (d) Theoretical, applied research.

- (e) The overall objective of the research is to develop a mathematical model of infiltration capable of responding to any spatial and temporal pattern of rainfall or its lack. In this form the model would be readily capable of integration into a general model simulating the hydrologic response of a watershed. In a first phase the objectives will be more limited. In essence the two principal objectives are the development of a one-dimensional model of water infiltration into a soil column under realistic conditions of varying water supply at the surface, nonuniform initial moisture conditions, heterogeneous soil characteristics and the effect of hysteresis, and the development of a less general two-dimensional model of water infiltration to model primarily the influence of spatial variation of the available water supply on infiltration.

- (g) Infiltration rates are affected by the characteristics of air motion in a manner quantitatively significant. Hysteresis, on the other hand, has little effect.

- (h) "General One-Dimensional Model for Infiltration," Le Van Phuc, M.S. thesis, Dept. of Civil Engrg., Colo. State Univ., December 1969 (83 pages).
"An Analytical Treatment of Two-Phase Flow During Infiltration," R. L. Brustkern, Ph.D. dissertation, Dept. of Civil Engrg., Colo. State Univ., March 1970 (105 pages).

(7247)

WATER RESOURCES OPTIMIZATION.

- (b) Colorado State University, Agricultural Experiment Station.

- (c) E. V. Richardson, Dept. of Civil Engrg.
- (d) Experimental, theoretical; applied research and development.

- (e) To research and apply methods to optimization of the water resources of Colorado. Studies include methods of reducing water loss by seepage, evaporation or transportation; to improve efficiency of the distribution systems by consolidation of conveyance systems; application of linear and dynamic programming, and design of conveyance systems.

- (g) A study was completed on the use of fluorescent dyes for the measurement and tracing of water. A study of ditch consolidation was made. Ground water quality study was completed.

- (h) "Irrigation System Consolidation," M. W. Biggs, Research Report, Colo. State Univ., Civil Engrg. Dept., Fort Collins, Colorado, 1968.
"Dye Dilution Method of Discharge Measurement," W. S. Liang, and E. V. Richardson, Colorado State University, Civil Engineering Department, Fort Collins, Colorado, 1969.

(7248)

WIND EFFECT ON REAERATION COEFFICIENT IN OPEN CHANNEL FLOW.

- (b) National Science Foundation.
- (c) Johannes Gessler, Asst. Prof., Dept. of Civil Engrg.
- (d) Experimental and theoretical basic research.
- (e) This study investigated the effect of wind gener-

ated waves on the reaeration coefficient. Experiments were performed in a combined wind-wave-tunnel.

- (f) Completed.

- (g) The observed increase in reaeration when wind is blowing was related back to the increased turbulence level at the water surface as induced by the wind-shear.

- (h) "Wind Waves and the Reaeration Coefficient in Open Channel Flow," A. F. Eloubaity, E. J. Plate, and J. Gessler, Dept. of Civil Engrg., Colorado State University, Technical Report, CER69-70AFE2, 1969.

(7249)

WIND EFFECT ON DISPERSION OF PARTICULATE POLLUTANTS IN A WIND-WATER-TUNNEL.

- (b) Atomic Energy Commission.

- (c) Johannes Gessler, Asst. Prof., Dept. of Civil Engrg.

- (d) Experimental, theoretical and basic research.

- (e) This study investigates the dispersion of particulate matter: a) in the wind boundary layer above the water and how it is affected by the wind generated waves, b) the dispersion of particles floating on the air-water interface as affected by wind generated waves, and c) the dispersion in the water (open channel flow with wind generated waves).

(7250)

FLOOD WAVES ASSOCIATED WITH RAPIDLY-VARIED UNSTEADY FLOW.

- (b) National Science Foundation.

- (c) A. H. Barnes, Associate Professor of Civil Engineering.

- (d) Experimental and theoretical applied.

- (e) To determine the effect of channel cross-section shape on open channel waves produced by a sudden release from a reservoir. The shapes considered were rectangular, triangular, and parabolic. Estimates were made of longitudinal water surface profiles and wave front velocity. Theoretical effect of roughness, channel slope, and initial dry bed were studied.

- (f) Suspended.

- (g) Significant differences were noted for different cross-sections.

(7251)

FIELD TESTING OF WATER PIPELINES.

- (b) Johns-Manville Sales Corporation.

- (c) Maurice L. Albertson, Department of Civil Engineering.

- (d) Experimental (laboratory) and field investigation; applied research (design) for Master's thesis.

- (e) The purpose of this project is to provide information for establishing better procedures for safely and completely testing in place the performance of water pipelines and to explain and describe these procedures adequately for use by the engineer and contractor. Specifically, the following aspects are being investigated: 1) Waterhammer resulting from the final stage of air exhaustion from pipelines and the associated rate of pipeline filling, and 2) current and proposed pressure testing procedures and limits.

(7252)

IMPACT OF TUBEWELLS AS A SOURCE OF IRRIGATION WATER IN THE PUNJAB OF WEST PAKISTAN.

- (b) Agency for International Development.

- (c) Maurice L. Albertson, Dept. of Civil Engrg.

- (d) Theoretical and field investigation; design and development for Ph.D. dissertation.

- (e) Interdisciplinary mathematical model using field

- data for optimization of canal water and tubewell water on the farm.
- (f) Field investigations under way. Initial data in process of analysis.

(7253) OPTIMIZATION OF WATER UTILIZATION FOR AGRICULTURAL PRODUCTION.

- (b) Agency for International Development.
- (c) Maurice L. Albertson, Dept. of Civil Engrg.
- (d) Theoretical; for Master's thesis and Ph.D. dissertation.
- (e) The purpose of this study is to determine a mathematical optimizing procedure of water resources development in developing countries with special emphasis on the agricultural aspects of the Indus Basin in West Pakistan and the Pa Mong Project, in the Mekong River Basin of Laos and Thailand.
- (g) Linear programming solution now being set up.

(7254) SYSTEMS ANALYSIS APPLIED TO WATER DEVELOPMENT AND OPERATION.

- (b) Agency for International Development.
- (c) Maurice L. Albertson, Dept. of Civil Engrg.
- (d) Theoretical applied research for master's thesis and doctoral dissertation.
- (e) Application of systems analysis and optimization techniques for the development and operation of West Pakistan water and power resources on a unified and comprehensive basis.
- (g) Work is in project synthesis stage.

(7255) TARBELA DAM PROJECT IN PAKISTAN.

- (b) Tippetts-Abbett-McCarthy-Stratton.
- (c) S. Karaki, Dept. of Civil Engrg.
- (d) Experimental; applied research.
- (e) This model study required the construction, operation, and analysis of a 1:12 scale hydraulic model consisting of one radial gate, immediately upstream and downstream portions of the fixed waterway, and the energy-dissipation chamber. An auxiliary model (scale 1:4) was proposed in order to provide supplemental information about localized flow phenomena and to assist in the proper design of the basic radial gate model. The purpose of the study was to obtain: (1) discharge coefficients at various gate openings, (2) pressure distribution on the gate face at various gate openings, (3) pressure in and near the wall recesses, and (4) behavior of high velocity jets at gate periphery when sealing force is released.
- (f) Completed.
- (g) Radial gates for high-head tunnel outlet control require special attention to structural geometry because of high velocities. The Tarbela gates were provided with seals on the skin plate and offset walls and floor to accommodate this seal placement. Solutions to special hydraulic problems arising from the design were provided.
- (h) "Final Report of the Model Studies of the Outlet Gates for Tunnels 3 and 4, Tarbela Dam Project, Indus River, West Pakistan," S. Karaki, A. G. Mercer, and J. P. Tullis, Dept. of Civil Engrg., Colorado State University, January 1970.
- "High Head Radial Gate Seals, A Hydraulic Model Study," S. Karaki, A. R. Luecker, J. Cleveland and A. G. Mercer, accepted for presentation at IAHR Symposium, Sweden, August 1970.

(7256) CHANGES IN BASIC PIPELINE FLOW CHARACTERISTICS CAUSED BY THE ADDITION OF POLYETHYLENE OXIDE.

- (b) Naval Ship Research and Development Center.
- (c) Raymond Converse, Physical Science Administrator, NSRDC; and J. Paul Tullis, Department of Civil Engrg.
- (d) Experimental; applied research and development.
- (e) An experimental program to investigate the effect of injecting polyethylene oxide solutions into developing boundary layers in pipe flow. Principal objectives of the study are: (1) to obtain information on the diffusion and rate of mixing of polymer solutions in developing boundary layers, (2) provide data at high shear rates for thick boundary layers for extending the drag reduction prediction techniques, (3) extend degradation information to high shear rates and thick boundary layers, (4) investigate new developments in polymer injection technology including direct slurry injection, and (5) provide a facility to assist in developing techniques and instrumentation for full-scale trial application.
- (f) Suspended.

(7257) CAVITATION SCALE EFFECTS FOR GENERALIZED VALVE SHAPES.

- (b) National Science Foundation.
- (c) J. Paul Tullis, Dept. of Civil Engrg.
- (d) Experimental; applied research.
- (e) Size and pressure scale effects are being evaluated for orifice plates that represent general types of valves. The intent is to generate sufficient data from which cavitation performance of various types of valves may be predicted.
- (g) Size and pressure scale effects have been evaluated. Adjustments must be made when using the results of model studies on valves at reduced size to predict the performance of larger valves operating at higher pressures. A new parameter (the critical cavitation pipe velocity V_c) is introduced and is suggested as a more appropriate parameter to use for valves. It appears to be more useful than the commonly used sigmas because it is simpler in form, has finite values for all types of valves over their complete range of operation, and allows scale effects to be more readily predicted.
- (h) "Predicting Cavitation in Valves," J. Paul Tullis, Raymond A. Hogan and N. C. Whittington, accepted for presentation at IAHR Symposium, Sweden, Aug. 1970.

(7258) EVALUATION OF PHYSICAL, CHEMICAL AND BIOLOGICAL QUALITY OF RESERVOIR WATER.

- (b) U.S. Bureau of Reclamation.
- (c) S. Karaki and J. Ward, Dept. of Civil Engrg.
- (d) Field investigation; applied research.
- (e) This study was conducted to determine the effect of impoundment on the quality of water in Cheney Reservoir. Physical, chemical and biological data were collected outside the framework of this study. This study concerned only the analysis of the data and the conclusions drawn from the analysis.
- (f) Completed.
- (g) Cheney Reservoir did not stratify during the period of data collection. Increase in the dissolved solids concentration was shown to be a direct result of evaporation; suggestions for control are made. Biological activity within this reservoir did not seem to affect the water quality materially. Data collected have been adapted to STORET, Washington, D. C.
- (h) "Evaluation of the Effect of Impoundment on Water

Quality in Cheney Reservoir," J. C. Ward and S. Karaki, Sanitary Engineering Paper No. 4, Colo. State University.

(7259)

HYDROLOGY OF SMALL WATERSHEDS.

- (c) E. F. Schulz, Associate Professor of Civil Engrg. Applied research.
- (e) A one-acre experimental watershed has been fitted with rainfall simulators. Rainfall can be uniformly applied to the watershed at rates varying from approximately 0.50 to 4.00 inches per hour. The runoff hydrograph is measured in a small H-flume and the rainfall and runoff data are automatically recorded on punched cards.
- (g) The kinematic wave theory of the formation of a flood hydrograph has been verified.
- (h) "Design and Testing of Rainfall Systems: Colorado State University Experimental Rainfall-Runoff Facility," M. E. Holland, CER 69-70 MEH 21, Nov. 1969.
"Overland Flow on a Converging Section," D. A. Woolhiser, Proc. ASAE, 1967.

(7260)

FLOODS FROM SMALL WATERSHEDS.

- (c) E. F. Schulz, Associate Professor of Civil Engrg. Applied research.
- (e) Flood hydrographs from small watersheds together with the hydrograph of causal rainfall and pertinent antecedent rainfall and physiography features of the catchment are assembled on magnetic tape. In some instances the frequency of the flood and rainfall are also assembled with the data. The data tapes are then used to provide basic data from natural watersheds for research in the theory of flood synthesis.
- (h) "Fluvial Physiography as a Factor in Basin Response," Mustafa Ulugar, Ph.D. dissertation, CSU, June 1969.

(7261)

CALIBRATION OF FLOW NOZZLES USING WATER WITH EXTRA-POLATION TO STEAM.

- (b) Westinghouse Electric Corporation.
- (c) Albert G. Mercer and R. H. Kilbane, Westinghouse.
- (d) Experimental; applied.
- (e) Calibration of flow nozzles in ERC calibration stand with interpolation to steam.
- (f) Completed.
- (g) Calibration is given as a function of Reynolds number, and a table is supplied giving flow rates for steam as a function of pressure difference.

(7262)

MODEL STUDY OF INTAKES TO TUNNEL 3 AND 4, TARBELA DAM.

- (b) Tippetts-Abbott-McCarthy-Stratton.
- (c) Albert G. Mercer and A. P. Luecker, TAMS.
- (d) Experimental; applied research.
- (e) Model study of intakes to diversion and irrigation release tunnels to determine their applicability to perform as anticipated.

(7263)

FLOOD PROTECTION AT CULVERT OUTLETS.

- (b) Wyoming State Highway Department.
- (d) Experimental and applied research.
- (e) Development of design criteria required to establish methods and the physical requirements of material necessary to control erosion and local scour downstream of highway culverts.
- (g) From model studies two types of concrete basins are being recommended for field use. Also, rock riprapped basin designs have been developed and

model tested.

- (h) "Flood Protection at Culvert Outlets," D. B. Simons, F. J. Watts, and M. A. Stevens, Report to the Wyoming Highway Dept., 152 pp., July 1969.
"Hydraulics of Rigid Boundary Basins," prepared by Colorado State University Civil Engineering Department, 239 pp., 1968.
"Forces on a Bed Particle in a Pumped Rock Stilling Basin," B. R. Urbonas, M.S. thesis, Colorado State University, 69 pp., March 1968.
"Hydraulics of Rigid Boundary Basins," F. J. Watts, Ph.D. dissertation, Colorado State University, 239 pp., August 1968.
"The Geometry of the Expanding Jet Downstream of Culverts," R. K. Stephen, M.S. thesis, Colorado State University, 139 pp., 1968.
"Scour at Culvert Outlets," T. R. Opie, M.S. thesis, Colorado State University, 82 pp., Dec. 1967.
"Scour in Riprap at Culvert Outlets," M. A. Stevens, Ph.D. dissertation, Colorado State Univ. 203 pp., January 1969.

A final report is being prepared and should be available by May, 1970.

(7264)

WATER RESOURCES HYDRAULICS.

- (b) Colorado State University Experiment Station.
- (d) Experimental, theoretical; applied research and development.
- (e) Emphasis has been given to the design and stabilization of canals and rivers and river response to development. Design methods have been developed to stabilize channels considering channel geometry, hydraulics, the properties of bed and bank material, turbulence, seepage, wave forms and other related factors. Similarly, techniques have been developed that help cope with the stabilization of channels at culvert outfalls and for various types of spillthrough structures such as bridge abutments and spur dikes.
- (h) "Stabilization of Alluvial Channels," D. B. Simons and N. G. Bhownik, presented at ASCE Natl. Meeting on Water Resources Engrg. New Orleans, Louisiana, 1969.
Closure to "River-Bed Degradation Below Dams," D. B. Simons and Saburo Komura, J. Hyd. Div., ASCE, Vol. 95, No. HY-3, 1969.
"Variation of α and β Values in a Lined Open Channel," D. B. Simons and Frederick J. Watts, Closure, J. Hyd. Div., ASCE, Vol. 95, HY-3, 1969.
"Open Channel Flow," Chapter 7 of Section entitled "Channel Flow" Text, Water, Earth, and Man edited by Richard J. Chorley, written by D. B. Simons, Methuen & Co., Ltd. 1969, pp. 297-318. Distributed in U.S. by Barnes & Noble, Inc.

(7265)

MATHEMATICAL MODELING OF SMALL WATERSHED FLOODS.

- (b) Office of Water Resources Research, Department of the Interior.
- (c) E. F. Schulz.
- (d) Applied research.
- (e) Various theories for predicting the flood response of a small watershed are verified from observation on the one-acre CSU experimental watershed. The optimized theory is then verified by observation of a natural flood on a small watershed.
- (h) "Summary of Experiments and Preliminary Results of an Experimental Investigation on the Kinematic Theory of Overland Flow," D. A. Woolhiser, 1969.

(7266)

TRANSPORT AND DISPERSION OF BED MATERIALS IN OPEN CHANNELS.

- (b) National Science Foundation.
- (c) H. W. Shen and P. Todorovic.
- (d) Theoretical and experimental.
- (e) To investigate both analytically and experimentally the transport and dispersion of bed material in open channels. A general stochastic sediment transport model will be developed and the theoretical results will then be compared with results obtained from the experiments in which radioactive particles are used as tracers.

(7267)

SEDIMENTATION AND CONTAMINANT CRITERIA FOR WATER RESOURCES PLANNING AND MANAGEMENT.

- (b) Office of Water Resources Research, and Colorado State Experimental Station.
- (c) H. W. Shen and D. B. Simons.
- (d) Theoretical and experimental.
- (e) Studying the effect of simulated vegetation on resistance to flow and sediment yield. Studying also the dispersion of contaminant.

(7268)

EQUIPMENT FOR BASIC RESEARCH ON TURBULENCE MECHANICS OF SHEAR FLOWS.

- (b) National Science Foundation.
- (c) L. V. Baldwin and R. D. Haberstroh.
- (d) The project is experimental; basic research for doctoral thesis.
- (e) The grant is for the design and construction of a re-circulating pipe flow apparatus that will enable basic turbulence data on shear flows of water to be obtained using hot-film anemometry equipment.
- (f) Completion expected June 30, 1970.
- (g) The apparatus will be initially employed to test a recent eddy viscosity hypothesis relating turbulence parameters to turbulent shear stress in flows.
- (h) "A Test of Phillips' Hypothesis for Eddy Viscosity in Pipe Flow," L. V. Baldwin and R. D. Haberstroh, AICHE Journal, Vol. 14, 825-826, September 1968.

(7269)

GROUND WATER RESERVOIR MANAGEMENT.

- (b) Colorado Experiment Station.
- (c) D. K. Sunada, Associate Professor and R. A. Longenbaugh, Assistant Professor.
- (d) Field studies, theoretical and applied.
- (e) This project is directed toward developing techniques for efficient ground water usage.
- (g) A mathematical model for the prediction of the physical response of water in an aquifer has been refined to include the movement of contaminants. In addition, work on the effects of capillarity (two phase flow) will be incorporated in the model by June 1970. Another model, showing how the use of water resources may be optimized, was also developed. This model uses the concept of dynamic programming to optimize the size of the development of a system composed of surface reservoirs, artificial recharge facilities, and a groundwater aquifer. Groundwater level measurements for eastern Colorado were measured in Spring, 1969 and reported in June, 1969. Reports on completed work were sent to State and Federal Agencies in Colorado.
- (h) "Dispersion in Groundwater Flow Systems," D. L. Reddell, Ph.D. dissertation, Colorado State Univ., Fort Collins, Colorado, December 1969.
- "Dynamic Programming in Water Resources," L.

Lopez-Garcia, M.S. thesis, Colorado State Univ., Fort Collins, Colorado, September 1969.

"Colorado Ground-water Levels," Spring 1969, J. Brookman, Colorado State University, Fort Collins, Colorado, July 1969.

"Aquifer Models: Mathematical and Physical," P. Stettner, M.S. thesis, Colorado State University, Fort Collins, Colorado, December 1968.

"Artificial Ground-water Recharge on the Arikaree River, Near Cope, Colorado," J. Brookman and D. K. Sunada, November 1968.

(7270)

FLOOD PROTECTION OF BRIDGES.

- (b) Wyoming State Highway Commission.
- (c) D. B. Simons, Professor and Associate Dean, and G. L. Lewis, GRA.
- (d) Experimental, theoretical, and applied research.
- (e) Development of a design procedure for riprap flood protection at bridges. The purpose is to develop, and experimentally test, an analytical model relating velocity fields to riprap protection in the vicinity of bridge approaches and abutments.
- (g) Modes of abutment failure and scour patterns have been experimentally observed and recorded. Laboratory tests of an analytical model indicate that theoretical velocities and boundaries from two-dimensional potential flow through a nozzle provide a first approximation to measured velocity fields for bridge approaches.
- (h) A doctoral thesis and a final report to the Wyoming State Highway Commission are being prepared and should be available by Jan. 1971.

COLUMBIA UNIVERSITY, Department of Civil Engineering and Engineering Mechanics, New York, New York 10027.
Professor Richard Skalak.

(6054)

VISCOUS FLOW IN A CYLINDRICAL TUBE CONTAINING A LINE OF PARTICLES OR DROPS.

- (b) Office of Naval Research; National Institutes of Health.
- (d) Theoretical; basic research; doctoral thesis.
- (e) Viscous flow in a circular cylindrical tube containing an infinite line of particles equally spaced along the axis of a cylindrical tube is considered neglecting inertial terms, as a model of blood flow in capillary blood vessels. Rigid spheroidal particles and liquid drops are considered.
- (g) The results show that the drag and pressure drop for spheroids decrease as the spacing between spheroids increases and for spacings more than one tube diameter, there is little interaction between particles. In the case of liquid drops, a non-Newtonian behavior for the suspension as a whole is predicted due to the deformation of the drops by the flow.
- (h) "Viscous Flow in a Cylindrical Tube Containing a Line of Spherical Particles," H. Wang and R. Skalak, J. Fluid Mech., Vol. 38, part 1, pp. 75-96, 1969.
- "Spheroidal Particle Flow in a Cylindrical Tube," T. C. Chen and R. Skalak, ONR Proj. NR 062-393, Tech. Rept. No. 2, Nov. 1968.
- "Viscous Flow of a Suspension of Liquid Drops in a Cylindrical Tube," W. A. Hyman and R. Skalak, ONR Project NR 062-393, Tech. Rept. No. 3, Jan. 1969.
- "Extensions of Extremum Principles for Slow Viscous Flows," ONR Proj. NR 062-393, Tech. Rept. No. 4, April 1969.

UNIVERSITY OF CONNECTICUT, School of Engineering,
Storrs, Connecticut 06268. Professor C. J. Posey.
(Summer address: Rocky Mountain Hydraulic Laboratory,
Allenspark, Colorado 80510.)

- (5489)
**BOUND-ROCK EROSION PROTECTION FOR HIGHWAY DRAINAGE
DITCHES.**
(a) Institute of Water Resources; and State Highway
Department.
(d) Experimental; applied.
(e) Develop application of scientific erosion-
protection method to highway ditches.
Experiments will provide necessary design data
and develop construction methods for low-cost in-
stallations.
(f) Trial installation on route I-91 under continuing
observation; others being planned.

(5737)
**REDUCTION OF RIVER HEAT POLLUTION BY TURBULENCE STIM-
ULATION.**

- (b) Institute of Water Resources.
(c) Professor V. E. Scottron, Civil Engineering Dept.
(d) Experimental; applied research for doctoral
theses.
(e) The objective of this work is to break up strati-
fication of heated river flows by generation of
heavy turbulence. Turbulence due to natural
bottom roughness is investigated in addition to
studies on the influence of turbulence intensities
on diffusion coefficients. Both sets of experi-
ments involve low-speed air flows.
(f) Completed.
(g) Results: (1) High-turbulence levels from natural
bottom roughness do not penetrate far enough into
main flow to have much influence on diffusion at
thermal interfaces, (2) turbulence levels affect
diffusion coefficients very strongly; coefficient
varies approximately as the cube of the turbulence
intensity.
(h) "An Experimental Investigation of Turbulence Due
to Forms of Bed-Roughness," Sat Dev Khanna, dis-
sertation, University of Connecticut, June 1968.
(Available from University Microfilms, Inc., Ann
Arbor, Michigan).
Dissertation: "A Study of the Mixing of Heat
Stratified Flow Under Varying Turbulence Condi-
tions with Application to the Reduction of River
Heat Pollution," Alan Lee Prasuhn, University of
Connecticut, June 1968. (Available from University
Microfilms, Inc., Ann Arbor, Michigan).
"Reduction in River Heat Pollution by Turbulence
Stimulation," A. L. Prasuhn, and V. E. Scottron,
University of Connecticut, Civil Engineering
Department, Report No. 69-22, May 1969. (Reprinted
from Proceedings of the Annual North Eastern
Regional Antipollution Conference, July 22-24,
1968, University of Rhode Island.)

(5769)
FILTER EROSION PROTECTION.

- (b) Water Resources Institute.
(d) Basic research; experimental.
(e) To determine whether finest-grained non-cohesive
and/or cohesive materials can be protected by
Terzaghi-Vicksburg inverted filter.
(g) If undermining of erosion protection by leaching
out of material from underneath is to be avoided,
the layers must meet the Terzaghi-Vicksburg in-
verted filter specifications. Rapidity of fail-
ure is proportional to degree of departure from
the specifications.

- (h) "Erosion Prevention Experiments," C. J. Posey,
Proc. 13th Congress, I.A.H.R., Kyoto, V. 2, p.
211, 1969.

(7271)
**CRITICAL-DEPTH VERSUS DISCHARGE RELATIONSHIP FOR COM-
POUND CROSS-SECTIONS.**

- (d) Experimental and theoretical, basic, master's
thesis.
(e) Data have been gathered on depths of flow in a
channel of compound section (parts of channel
having much different depths) near a free overfall
and also where slope changes from steep to mild.
(f) Data being analysed and theories tested.

(7272)
**EXPERIMENTAL STUDIES OF AIR AND WATER INTERFACIAL
INTERACTION.**

- (b) Institute of Water Resources.
(c) Dr. J. D. Lin, Civil Engineering Department.
(d) Experimental; basic research for master's and
doctoral theses.
(e) Experimental investigation of the interaction
mechanics with application to the process of
dispersion, mixing and diffusion of surface
pollutant under the action turbulent wind.

CORNELL AERONAUTICAL LABORATORY, INC., OF CORNELL
UNIVERSITY, P. O. Box 235, Buffalo, New York 14221.
Robert S. Kelso, President.

(5363)
**UNSTEADY FORCES AND MOMENTS ON A TWO-DIMENSIONAL
FULLY CAVITATED HYDROFOIL.**

- (b) Naval Ship Research and Development Center, and
Office of Naval Research, Dept. of the Navy.
(c) Dr. Irving C. Statler, Senior Staff Scientist,
Aerodynamics Division.
(d) Applied research; theoretical.
(e) The purpose of the project is to determine the
steady and unsteady forces and moments on a fully
cavitating hydrofoil operating near a free sur-
face. The approach being taken is based on a
linearized flow model of a fully cavitating flat
plate which is in steady or harmonic motion near
a free surface. Full account is taken of the
gravity waves generated by the motion of the foil
and cavity and cavitation numbers greater than or
equal to zero are considered.
(f) Suspended.
(g) The status report discusses the approach to the
general problem which is based on a representa-
tion of the system by distributions of elemental
singularities and on a double linearization pro-
cedure. The latter feature separates the problem
into a quasi-steady and an unsteady part in which
the governing equations of the unsteady problem
depend on the solutions to the quasi-steady prob-
lem. The quasi-steady solution is obtained for
a supercavitating, flat-plate foil near a free sur-
face taking account of the effects of gravity.
Results for the limiting case of steady motion
are compared with other theories and with experi-
mental data.
(h) "A Theoretical Study of the Force and Moment on
an Oscillating Supercavitating Hydrofoil Near a
Free Surface," C. Tung and I. C. Statler, Cornell
Aero. Lab. Rept. No. BB-2395-S-1, November 1967.

(6178)

A LABORATORY AND FIELD STUDY OF THE EFFECT OF WAVES ON THE EVAPORATION FROM A FREE WATER SURFACE.

- (b) Bureau of Reclamation, Dept. of the Interior.
- (c) Mr. Calvin Easterbrook, Principal Physicist, Applied Physics Department.
- (d) Applied research; experimental, laboratory and field.
- (e) This study has been directed towards evaluating the effects of waves on a water surface on the evaporation rate from that surface. The work began as a laboratory study, wherein measurements were made using a large wave-tank and wind-tunnel combination. The apparatus was designed so that both wind speed and wave parameters could be controlled. Waves were generated in the tank by a hydraulically driven paddle, thus permitting simulation of conditions associated with larger bodies of water (fetches up to a mile or more). The project was extended to include field studies at Lake Hefner in Oklahoma. Here wind, wave and evaporation data have been acquired which will permit computation of parameters comparable to those measured in the laboratory work.
- (f) Completed.
- (g) Results of the laboratory experiments show that evaporation rates are reduced under certain combinations of waves and wind speed. Preliminary analysis of the field data tend to support the laboratory findings. The influence of waves on evaporation rate appears to be caused by modification of the air flow over the water surface in a manner which reduces the vertical transport of water vapor in the boundary layer.
- (h) Final Report, "A Study of Spray and its Contribution to Total Evaporation," Calvin C. Easterbrook, Cornell Aero. Lab. Rept. No. RM-2865-P-1, January 23, 1970.

(6179)

DEEP SUBMERGENCE RESCUE VEHICLE STUDIES.

- (b) Naval Ship Systems Command, Dept. of the Navy.
- (c) Mr. Roy S. Rice, Jr., Head, Vehicle Dynamics Section, Vehicle Research Department.
- (d) Applied research; experimental.
- (e) This project continued the investigation of the performance characteristics of tandem propellers in developing roll control, verified the theory that increases in vehicle velocity in any direction orthogonal to the propeller axis caused an increase in control force to power ratio, and investigated the "anti-mud" mode of operation in near silt-bottom hovering operations of underwater vehicles.
- (f) Completed.
- (g) The Tandem Propeller concept of submersible vehicle propulsion and control has been previously shown to offer excellent maneuvering capability in applications to low-speed underwater craft. The studies described in these reports were performed in order to investigate the sensitivity of this capability to a number of specific operating conditions. An experimental program consisting of tests of pure axial thrusting performance, combined cyclic and collective blade pitch variations, development of controlled roll moments, and near-bottom operation is described. Refinements to an engineering theory of propeller performance based on the results of these tests are discussed. Tests demonstrated the "anti-mud" mode capability wherein water motion directly beneath the submersible can be minimized. Also, dynamic response of the propeller in generating propulsion and control forces is excellent. Detailed test results are shown to support an

evaluation of the system which suggests that it has special merit for application to deep submersible vehicles.

- (h) "Experimental Studies of Tandem Propeller Performance at Static Conditions," R. S. Rice, Jr., Cornell Aero. Lab. Rept. No. AG-2381-K-2, Feb. 1968.
- "Experimental Studies of Tandem Propeller Performance at Static Conditions," F. R. Haselton, Cornell Aero. Lab. Rept. No. AG-2381-D-3, April 1968.

(7273)

AQUA - MAP PHASE I.

- (b) State of New York, Division of Water Resources, Conservation Department.
- (c) Dr. Robert C. Ziegler, Head, Remote Sensing Section.
- (d) Theoretical research, laboratory and field.
- (e) In this program, laboratory experiments were performed to determine the feasibility of using aerial photographic techniques for water resources research, in particular, for detecting, classifying, and measuring concentrations of effluents. The spectral reflectance characteristics of several effluents were measured and suggestions were made for optimizing the detection and identification of these discharges. In addition, factors influencing the selection of sites for aerial photographic experiments were analyzed. The Finger Lakes and Lake Chautauqua were considered as well as the Niagara Frontier.
- (f) Completed.
- (g) The study indicated that it is feasible to enhance the photographic contrast of discharges with respect to their backgrounds and, with appropriate controls, to use spectral signatures for classifying types of discharges and for measuring concentration over certain ranges.
- (h) Final Report VT 2449-0-1. Copies of this report are obtained through request of the sponsor.

(7274)

AQUA - MAP PHASE II.

- (b) State of New York, Division of Water Resources, Conservation Department.
- (c) Dr. Robert C. Ziegler, Head, Remote Sensing Section, Observation Sciences Department.
- (d) Theoretical research; laboratory and field.
- (e) In this phase of the AQUA-MAP Program, aerial photographic flights were conducted in the Buffalo area over the Niagara River and Tonawanda Creek. The types of discharges imaged were studied in the laboratory under controlled conditions. Additional laboratory measurements have been made of the spectral reflectance characteristics of water samples taken from the Niagara River and Tonawanda Creek to supplement the data obtained during Phase I on discharges. Theoretical investigations into the mechanics of scattering by polluted aqueous solutions were examined. Laboratory and aerial validation of the theory was performed, the intent being to allow a realistic model of polluted bodies of water to be created.
- (f) Completed.
- (g) Such a model will serve to aid the identification of pollutants via aerial photographs and also indicate the limitations of remote sensing analysis.
- (h) Final Report VT 261401; copies of this report are obtained through request of the sponsor.

(7275)

CALORIC.

- (b) New York State Electric & Gas.
- (c) Dr. Robert C. Ziegler, Head, Remote Sensing Section, Observation Sciences Department.
- (d) Applied research; laboratory and field.
- (e) The object of the program was to investigate the thermal pattern in the vicinity of an existing electrical power station and to develop an analytical model for predicting the thermal pattern that will prevail during the operation of a planned nuclear facility near an existing plant. This program was designed to provide information for assessing the influence of the future thermal discharge from the nuclear plant on the ecology of the Lake and for determining the preferred locations of the intake and discharge tunnels of that plant. The program consisted of three tasks: (1) the development of an analytical model of the thermal characteristics of the Lake, (2) measurement of the surface temperature distribution of the Lake using an airborne infrared radiometer, and (3) the design, fabrication and installation and routine maintenance of temperature and lake current instrumentation.
- (f) Completed.
- (g) A Summary Report and a Final Report were published, Physical Effects Final Report Summary, CAL. No. VT 2616-01, Technical Reports, VT 2616-0-2, VT 2616-0-3; copies of these reports are obtained through request of the sponsor.

(7276)

BUFFALO RIVER PROJECT.

- (b) City of Buffalo for FWPCA.
- (c) Dr. Robert C. Ziegler, Head, Remote Sensing Section, Observation Sciences Department.
- (d) Applied research; laboratory and field.
- (e) The Buffalo River Project is a two-phase program for preventing and eliminating oil pollution of the Buffalo River. Phase I is concerned with specifying oil containment and removal equipment which includes air barriers, surface booms, debris catches, and skimmers, both portable and fixed. This phase also provides for evaluation of performance and cost analysis of operation of this equipment under various climate and flow conditions. Sampling and analysis techniques to determine quantities and types of oil present will be developed. Phase II is a development and evaluation of instrumentation to detect oil in a combined sewer system. This includes a small scale alarm system to alert officials of an oil spill. Methods will also be investigated to prevent oil from entering the River at times of sewer overflow.
- (g) Results: An air barrier has been developed and tested for restraining surface oils. Surface barriers have been installed and tested for restraining surface oil and debris, instrumentation to detect oil in combined sewers has been developed and is currently being tested.
- (h) Annual Report summarizing 1st year's effort issued February 27, 1970, copies of this report are obtained through request of the sponsor. Final Report to be issued January 1971.

CORNELL UNIVERSITY, School of Civil Engineering, Department of Water Resources Engineering, Ithaca, New York 14850. Dr. J. A. Liggett, Associate Professor.

(4531)

SECONDARY CURRENTS IN NON-CIRCULAR CONDUITS.

- (b) National Science Foundation.
- (d) Theoretical and experimental.
- (e) Those secondary currents caused by Reynold's stresses in straight, non-circular conduits are being studied. A triangular open channel is being used. Measurements are to be taken by the hot-film anemometer.
- (f) Completed.
- (g) A quantitative theory has been developed and is being tested.
- (h) "Flow in a Sharp Corner," R. J. Matthews and J. A. Liggett, J. Hyd. Div., ASCE, Vol. 93, Nov. 1967.

(5303)

RECESSION HYDROGRAPHS OF IDEALIZED UNCONFINED AQUIFERS.

- (c) Dr. W. H. Brutsaert.
- (d) Experimental and theoretical.
- (e) A Hele-Shaw model has been constructed to study the different parameters affecting drainage from large unconfined geological formations into stream channels. The obtained ground water recession hydrographs are compared with those derived from previous theoretical, but approximate, solutions. New theoretical analyses are being developed.
- (h) "On the First and Second Linearization of the Boussinesq Equation," Wilfried Brutsaert and H. A. Ibrahim, Geophys. J. Roy. Astr. Soc., Vol. 11, 549-554, 1966.

(5305)

THE PHYSICAL PHENOMENA INVOLVED IN PAN EVAPORATION.

- (c) Dr. W. H. Brutsaert.
- (d) Theoretical and experimental.
- (e) Evaporation is being measured from a number of insulated shallow pans of different sizes and colors. These experimental results and simultaneous climatological data will be used to check and extend some theoretical models of the hydrodynamics--and also of the energy budget aspects of pan evaporation and evaporation in general.
- (h) "Evaporation from an Extremely Narrow Wet Strip at Ground Level," W. H. Brutsaert, and G. T. Yeh, J. Geophysical Res., Vol. 74, No. 13, 3431-3433, 1969.

(5306)

THE HYDRAULICS OF POROUS MEDIA.

- (c) Dr. W. H. Brutsaert.
- (d) Theoretical and experimental.
- (e) An analysis is being made of moisture characteristic curves of porous media to describe the pore size distribution by mathematical equations. These distributions are used to calculate hydraulic properties of the media.
- (h) "The Permeability of a Porous Medium Determined from Certain Probability Laws for Pore Size Distribution," W. Brutsaert, Water Resour. Res., Vol. 4, 1968.

(5307)

MECHANICS OF INFILTRATION.

- (c) Dr. W. H. Brutsaert.
- (d) Theoretical.
- (e) The micro-hydrological equations of unsaturated flow in porous media are being investigated and

solved for different boundary conditions. The results of the mathematical analysis are extended to develop infiltration equations for larger areas or for an entire watershed.

- (h) "Intermittent Infiltration into Soils with Hysteresis," H. A. Ibrahim and W. Brutsaert, Proc. ASCE, J. Hyd. Div., Vol. 93, HY1, 1968.

(5874)

MATHEMATICAL FLOW ANALYSIS.

- (b) U.S. Department of the Interior.
(c) Theoretical.
(e) The equations of continuity and momentum are being solved on a digital computer in order to analyze unsteady flow over surfaces and in channels.
(h) "Mathematical Flow Determination in Open Channels," J. A. Liggett, J. Engrg. Mech. Div., ASCE, EM4, August 1968.

(7277)

WIND-DRIVEN LAKE CIRCULATION.

- (b) National Science Foundation.
(d) Theoretical.
(e) Mathematical models are constructed in order to determine the circulation in lakes. Both numerical and analytical methods are used. The model considers both steady and unsteady states in homogeneous and stratified lakes.
(h) "Circulation in Shallow Homogeneous Lakes," J. A. Liggett and C. Hadjithodorou, J. Hyd. Div., ASCE, March 1969.
"Unsteady Circulation in Shallow Homogeneous Lakes," J. A. Liggett, J. Hyd. Div., ASCE, July 1969.
"A Cell Method for Computing Lake Circulation," J. A. Liggett, J. Hyd. Div., ASCE, March 1970.

(7278)

HEAT AND WATER VAPOR EXCHANGE BETWEEN WATER SURFACE AND ATMOSPHERE.

- (b) FWPCA.
(c) Dr. W. H. Brutsaert.
(d) Theoretical.
(e) The investigation involves the study of the physical and mathematical foundations underlying simultaneous turbulent heat and water vapor exchange between a large open water body and surrounding atmosphere for various conditions of local atmospheric advection and of solar and other energy inputs into the water body. The main objective of the research is to gain a better understanding of these phenomena in order to assess and improve the presently available theoretical models. This will then in turn allow the development of practical engineering procedures to better predict cooling and evaporation from water reservoirs, especially in connection with thermal power station design, than is possible at present.

DARTMOUTH COLLEGE, The Thayer School of Engineering,
Hanover, New Hampshire 03755. Graham B. Wallis,
Associate Professor.

(7280)

ONE-DIMENSIONAL TWO-PHASE FLOW.

- (b) National Science Foundation.
(d) Theoretical and experimental basic research.
(e) Establishment of a unified basic theory with numerous applications.
(h) "Two-Phase Gas-Liquid Nozzle Flow,"
"One-Dimensional Waves in Two-Phase Flow;"

"The Separated Flow Regime of Two-Phase Flow;"
"Condensation in Straight Pipes."

UNIVERSITY OF DELAWARE, College of Engineering,
Department of Civil Engineering, Newark, Delaware
19711. Dr. Eugene Chesson, Department Chairman.

(5047)

WAVE DAMPING DEVICES.

- (b) Project Thesis.
(c) Dr. Kurt P. H. Frey, Professor Emeritus and Investigator.
(d) Experimental, applied research, open end for theses.
(e) Capacitance methods and techniques developed under (6371) for multiple wave probe measurements have been simultaneously employed with strain gage force measurements in waves up to 3 in. high. The initially chosen staffed vane model has been modified and numerous other related devices have been tested in order to identify which phenomena are most significant in the efficient damping of waves. First tentative application: large tow-wave tank.
(g) The experimental methods and techniques employed with advanced oscilloscopes or multiple channel oscillograph are working fully satisfactorily. The scope of the studies turned out to be significant for adequate progress and as a basis for meaningful theory.

(6367)

HYDRODYNAMIC MASSES ASSOCIATED WITH FLOATING AND SUBMERGED BODIES.

- (c) W. S. Gaither, Associate Professor.
(d) Theoretical and experimental.
(e) The purpose of these studies is to understand the mechanics of fluid motion which brings about the formation of a hydrodynamic mass associated with floating and submerged bodies with particular reference to ship hulls.

(6371)

STUDIES ON MECHANICS OF FLUID FLOW.

- (b) Defense Department (joint School of Engineering, Fluid Mechanics and Heat Transfer Thesis Project), Harry Diamond Laboratory (U.S. Army Materiel Command).
(c) Dr. Kurt P. H. Frey, Professor Emeritus and Investigator.
(d) Experimental, basic and applied research, design, development, basis for master's and doctoral theses.
(e) Applicability of hydrogen bubble method extended to low depths by adjustable glass bottom with lighting. Application of the capacitance method to record simultaneously and instantaneously at multiple locations by partially submerged probes or probes above the water changes of water surface levels. Hypodermic needle dye injections have been introduced also. A rail system has been provided (stainless steel) with a multiple purpose carriage and an instrument carrier. Photographic and lighting equipment has been adequately improved and adequate oscilloscopes and oscillographs successfully used. Principal purpose: transition to more sophisticated, advanced experimentation.
(f) Mostly completed.
(g) Purpose achieved so far. Hydrogen bubble method now applicable from 0.5 to 16 in. depths. Surface changes measured from 0.1 mm to 75 mm. Reynolds number range lowered to 200. Output-

- input oscillator has been materialized in the flume using methods and techniques of (e).
- (h) "Low Aspect Ratio, Low Reynolds Number Diffuser Flows," R. P. Trask II, Master's thesis, Memorial Library, University of Delaware, 1969.

(7281)
RESEARCH IN THE COASTAL AND OCEANOGRAPHIC ENVIRONMENT.

- (b) Department of Defense.
- (c) W. S. Gaither, Associate Professor.
- (d) Applied and basic; master's and doctoral programs.
- (e) A section of the Atlantic coast between Atlantic City, New Jersey and Ocean City, Maryland is being used as the site for a comprehensive interdisciplinary study of the nearshore and coastal environment. Wind, wave, current and other forces affecting this coastal region are being examined in a sector of the ocean extending beyond the Continental Shelf and into the backshore area to the landward boundary of lagoon marshes. Portions of Delaware Bay are included in various subprojects as required for continuity. The focus of this project is basic research on the coast and ocean environment. The knowledge gained will be applicable to many typical coastal and Continental Shelf problems in similar environments throughout the world. The project approach involves an analysis of the energy inputs to the study area and its modes of dissipation. Meteorologic and engineering studies consider air-sea and air-land interaction as related to energy transfer, boundary effects, the influence of surface agents and general problem of nearshore wave damping. The geologic structure of the coastal region is being examined as a basis for studies of surface erodibility, sediment transport, the support of aquatic and marsh vegetation, and the effect of marine organisms on the coastal configuration. The geologic structure is also being related to groundwater movement and the positions of the salt-fresh water interface. Soil studies are concerned with sampling, classification, determination of mechanical properties, permeability, organic content and other parameters. Probabilistic correlation studies are being made between storm occurrences, wave heights, erosional effects and ecological patterns as a basis for establishing engineering design criteria. A comprehensive remote sensing program is being conducted to establish correlations between various qualitative parameters such as soil strength and trafficability as well as to relate surface and subsurface conditions. Conferences and symposia are planned as an integral part of the program.

(7282)
STUDY OF ENERGY BUDGET IN DELAWARE OCEAN FRONTIAGE AND BAY.

- (b) Office of Naval Research; Defense Department (Joint University project "Themis").
- (c) F. E. Canfield, Assistant Professor.
- (d) Experimental and theoretical; basic research.
- (e) Physical and mathematical models are to be developed to describe and predict wave and current action on the Delaware coastline and within the mouth of Delaware Bay. Particular emphasis is to be made on studying the area including Cape Henlopen. Studies will be made of sediment movement with emphasis on the prediction of sediment movement. Comparisons will be made with the results of geological investigations of the area.

(7283)
GROUND WATER BEHAVIOR IN THE LITTORAL AND BACKSHORE MARSH REGIONS.

- (b) Department of Defense.
- (c) Robert D. Varrin, Assistant Professor.
- (d) Experimental; applied research.
- (e) The ground water behavior in the littoral and backshore marsh region of a portion of the Delaware coast will be investigated by means of a vertical (Hele-Shaw) analog model.
- (g) A comprehensive report has been compiled on the existing ground water data in the littoral and backshore areas from Atlantic City, New Jersey to Ocean City, Maryland.

UNIVERSITY OF DELAWARE, Department of Chemical Engineering, Newark, Delaware 19711. Arthur B. Metzner, Department Chairman.

(7284)
TURBULENT FLOWS IN DRAG REDUCING SOLUTIONS.

- (b) Department of Defense (Project Themis).
- (c) Michael R. Samuels.
- (d) Experimental, basic research.
- (e) A laser doppler velocimeter is being built, and will be used to measure velocity probability distribution functions, and power spectra for transitional and turbulent drag reducing polymer solutions.
- (g) Velocimeter in operation; however, no turbulence measurements accomplished yet.

(7285)
LAMINAR FLOW FIELDS IN SUDDEN CONTRACTIONS AND EXPANSIONS.

- (c) Michael R. Samuels.
- (d) Theoretical, basic.
- (e) Numerical techniques are being used to solve the Navier - Stokes equations for laminar flow in a sudden contraction or expansion in circular pipes. Radius ratios between 1 and infinity are being investigated.
- (g) Programs are operational for both expansion and contraction, and various radius ratios and Reynolds numbers are being investigated.

DOUGLAS AIRCRAFT COMPANY, MCDONNELL DOUGLAS CORPORATION, Aerodynamics Research, 3855 Lakewood Blvd., Long Beach, California 90801. W. T. Dickinson, Vice President, Research and Technology.

(6546)
INCOMPRESSIBLE FLAT PLATE LAMINAR BOUNDARY LAYER IN WATER WITH TEMPERATURE DEPENDENT VISCOSITY.

- (c) Mr. T. T. Okamura, Engineer/Scientist Specialist.
- (d) Theoretical basic research.
- (e) The Orr-Sommerfeld equation, modified to include the effect of temperature dependent viscosity, is solved "numerically". Complete spatial and temporal stability characteristics were calculated as a function of wall temperature to Reynolds numbers $Re_w = 100,000$. The work is part of an effort to correlate transition with linear stability theory.
- (f) Completed.
- (g) It is found that heating stabilizes the flow and cooling destabilizes it. For a given free-stream temperature and a variable wall temperature, the critical Reynolds number and rates of amplification exhibit a maximum. The effect of heating upon the amplification rates is much more pro-

nounced than its effect upon the critical Reynolds number. Cooling the boundary layer leads to inflected profiles and thus introduces elements of inviscid instability.

The magnitude of the effect of heat transfer upon stability characteristics, critical Reynolds number, spatial and temporal amplification rates, etc., is found to depend upon the pressure gradient. The effect is more pronounced the more negative the pressure gradient is. The effect of wall temperature upon stability is partially accounted for by the variation of inflection point with heat transfer. Charts suitable for predicting the variation of the transition Reynolds number with temperature are presented.

- (h) "Incompressible Flat Plate Laminar Boundary Layer in Water with Temperature Dependent Viscosity," A. R. Wazzan, T. T. Okamura, A. M. O. Smith, presented at the Sixth Southeastern Seminar on Thermal Sciences, Raleigh, North Carolina, 13 April 1970.
- "The Stability and Transition of Heated and Cooled Incompressible Laminar Boundary Layers," A. R. Wazzan, T. T. Okamura, and A. M. O. Smith, presented at the Fourth International Heat Transfer Conference, Paris, France, 31 August - 5 September 1970.

(6548)

CALCULATION OF POTENTIAL FLOW ABOUT ARBITRARY CONFIGURATIONS.

- (b) Naval Air Systems Command.
- (c) J. L. Hess, Chief, Basic Research Group.
- (d) Theoretical applied research.
- (e) Develop methods for calculating incompressible flow with no geometrical restrictions on the flow boundaries. Underlying method is based on an integral equation for source density distribution on boundary surfaces. Effort directed towards working computer programs that reduce the integral equation to a matrix equation and solve it. Separate programs exist for different types of geometry - two-dimensional, axisymmetric, and three-dimensional - and for different flow conditions. Presently lift can be accounted for only in two dimensions.
- (g) Current activity directed towards calculating three-dimensional lifting effects. Logic and formulas largely programmed and are being checked out.
- (h) "Calculation of Potential Flow about Arbitrary Three-Dimensional Lifting Bodies. Phase I. Final Report," John L. Hess, McDonnell Douglas Report No. MDC-J0545, December 1969.

(7286)

STATIC PRESSURE PROBES THAT ARE THEORETICALLY INSENSITIVE TO PITCH, YAW, AND MACH NUMBER.

- (c) Dr. A. B. Bauer, Senior Engineer/Scientist.
- (d) Experimental and theoretical applied research.
- (e) The idea of distributing static probe cross-sectional areas so as to render the probe insensitive to Mach number is combined with that of using noncircular cross sections to render probes insensitive to yaw and angle of attack.
- (g) Appropriate noncircular cross sections have been described in detail, and a general means of designing blunt or slender probes to have zero sensitivity to yaw and angle of attack in potential flow has been developed. Four experimental probes have been tested, and test results are available. These results show that the probes are quite insensitive to yaw and angle of attack within certain limiting angles, which are assumed to correspond to the onset of flow separation.

ration.

- (h) "Static Pressure Probes that are Theoretically Insensitive to Pitch, Yaw, and Mach Number," A. M. O. Smith and A. B. Bauer, presented at 6th U.S. National Congress for Applied Mechanics, Harvard University, Cambridge, Massachusetts, June 1970.

(7287)

THE STABILITY OF INCOMPRESSIBLE TWO-DIMENSIONAL WAKE FLOWS.

- (c) Mr. T. T. Okamura, Engineer/Scientist Specialist.
- (d) Theoretical basic research.
- (e) The spatial stability characteristics predicted from linear theory were used to correlate with measurements in the form of a flat plate obtained by Sato and Kuruki. The frequency of natural fluctuations as well as amplitude variations within the boundary layer agree favorably with experiment.
- (f) Completed.
- (g) The theoretical results of the present spatial analysis agree better with experiment than temporal results predicted by either Sato and Kuruki or H. Gold presented in previous works.
- (h) "The Stability of the Incompressible Two-Dimensional Wake Flows," A. R. Wazzan and T. T. Okamura, McDonnell Douglas Report No. DAC 67958, June 1969.

(7288)

FUNDAMENTAL BOUNDARY LAYER AND DRAG STUDIES.

- (b) Naval Ship Research and Development Center.
 - (c) Dr. T. Cebeci, Senior Engineer/Scientist.
 - (d) Theoretical applied research.
 - (e) Develop methods for calculating laminar and turbulent boundary layers about two-dimensional and three-dimensional bodies so that aerodynamic forces can be calculated accurately. Presently this effort has succeeded in developing a very accurate method for calculating laminar and turbulent boundary layers about two-dimensional and axisymmetric bodies. The method employs a finite-difference method. The computation time is quite small. The method has also the capability of calculating boundary layers with heat and mass transfer.
 - (g) Current activity directed toward laminar and turbulent flows about three-dimensional flows. Studies are also being conducted to calculate the total drag of airfoils and bodies of revolution.
 - (h) "Recent Progress in the Calculation of Turbulent Boundary Layers," T. Cebeci, and A. M. O. Smith, presented to the 8th U.S. Navy Symp., Corona, California, May 1959, also Douglas Engineering Paper 5531.
 - "Calculation of Compressible Adiabatic Turbulent Boundary Layers," T. Cebeci, A. M. O. Smith, and G. Mosinskis, Paper 69-687 presented to AIAA 2nd Fluid and Plasma Dynamics, San Francisco, Calif., June 1969. To be published in the AIAA Journal.
 - "Calculation of Heat and Mass Transfer in Turbulent Flows at Low Mach Numbers," T. Cebeci, and G. J. Mosinskis, McDonnell Douglas Rept. DAC 70015, Oct. 1969.
- (7289)
- #### BOUNDARY-LAYER STABILITY AND TRANSITION.
- (c) Dr. N. A. Jaffe, Senior Engineer/Scientist.
 - (d) Theoretical applied research.
 - (e) Stability characteristics of incompressible laminar boundary layers on two-dimensional or axisymmetric bodies are obtained from solutions to the Orr-Sommerfeld equation. Studies are in progress attempting to correlate the amplifica-

tion of disturbances with the experimentally observed location of transition for flows having very low free-stream turbulence levels. The purpose of the investigation is to ascertain whether or not classical linearized stability theory can be used as a tool to predict transition.

- (g) For a number of flows studied, it has been found that the value of the ratio of the disturbance amplitude at transition to its value at the location of neutral stability for the frequency producing the maximum amplification ratio is of the order of e^{10} .
- (h) "The Determination of Spatial Amplification Factors and Their Application to Predicting Transition," N. A. Jaffe, T. T. Okamura, and A. M. O. Smith, presented at AIAA 7th Aerospace Sciences Mtg., New York, AIAA preprint 69-10, Jan. 1969. To be published in the AIAA Journal.

(7290)

OPTIMIZATION OF AIRFOILS FOR MAXIMUM LIFT.

- (c) Dr. R. H. Liebeck, Senior Engineer/Scientist.
- (d) Theoretical applied research.
- (e) The pressure distribution which provides the maximum lift without separation for a monoelement airfoil in an incompressible flow has been determined using existing boundary-layer theory and the calculus of variations. The airfoil profiles corresponding to these pressure distributions were first determined using second-order airfoil theory.
- (f) The method is now being refined and extended to obtain exact solutions. Also, a wind tunnel evaluation program is being planned.
- (g) Initial results indicate maximum lift coefficients as high as 2.8 for Reynolds numbers of between five and ten million, and the corresponding drag coefficients are on the order of 0.01. It is expected that the exact solution will yield even better performance.
- (h) "Optimization of Airfoils for Maximum Lift," R. H. Liebeck and A. I. Ormsbee, presented at the CASI/AIAA Aero-Hydro/Mechanics Meeting, Ottawa, Canada, July 1969. To be published in the AIAA Journal of Aircraft.

DREXEL UNIVERSITY, Department of Civil Engineering,
Philadelphia, Pennsylvania 19104. Dr. A. A.
Fungaroli.

(7291)

POLLUTION OF SUBSURFACE WATER BY SANITARY LANDFILL.

- (b) Public Health Service, Office of Solid Waste.
- (d) Experimental, theoretical and field investigation. Applied research.
- (e) The comprehensive long-range objectives are: to provide means for predicting the movement of pollutants in subsurface water from existing and proposed sanitary landfills; to develop hydrologic, geologic and soil criteria for the evaluation of site suitability for sanitary landfilling operations, and to appraise design methods and remedial procedures for reducing any undesirable contaminant movement that the study may disclose.
- (h) "Design of a Sanitary Landfill Laboratory Lysimeter," A. A. Fungaroli and R. L. Steiner, Drexel Univ., Series I, No. 9, 1968.
"Design of a Sanitary Landfill Field Experiment Installation," A. A. Fungaroli and R. L. Steiner, Drexel Univ., Series I, No. 10, 1968.
"Foundation Problems in Sanitary Landfills," R. L. Steiner and A. A. Fungaroli, J. Sanitary Engrg. Div., A.S.C.E., Vol. 94, No. SA4, Aug. 1968.

"Sanitary Landfill - A Bibliography," R. L. Steiner and Renee Kantz, U. S. Dept. of Health, Education and Welfare, Publ. No. 1819, 1968.
"Analytical Procedures for Chemical Pollutants," A. A. Fungaroli and R. L. Steiner editors, Drexel Univ., Series I, No. 8, 1968.
"Water Movement in an Unsaturated Sanitary Landfill," I. Remson, A. W. Lawrence and A. A. Fungaroli, J. Sanitary Engrg. Div., A.S.C.E., Vol. 94, No. SA2, Aug. 1968.
"Construction of Laboratory and Field Facilities for the Investigation of Leaching from Sanitary Landfills," Second Mid-Atlantic Industrial Waste Conf., Drexel Univ., Nov. 1968.

Reprints for all of the above referenced articles may be obtained through Drexel University, c/o Dr. A. A. Fungaroli.

THE FRANKLIN INSTITUTE RESEARCH LABORATORIES, Mechanical and Nuclear Engineering Department, The Benjamin Franklin Parkway, Philadelphia, Pennsylvania 19103.
W. H. Steigelmann, Manager, Heat & Fluid Mechanics.

(7280)

FLOW MODELING STUDIES FOR WATER-COOLED REACTORS.

- (d) Experimental.
- (e) Several flow model studies have been made using pressurized carbon dioxide to simulate the flow of pressurized water. The use of pressurized carbon dioxide permits high Reynolds numbers to be attained because of the unusually low kinematic viscosity of this fluid. An incidental advantage is that the required pressures are obtained by charging the supply tanks with dry ice, so that compressors are not needed as part of the facility. Measurements made with the CO₂ flow model include flow distribution, pressure distribution, and mixing. Flows are generally measured by sensing the pressure drops across orifices that simulate the hydraulic resistances of flow passages. Flow patterns in other regions have also been studied by injecting cooled carbon dioxide at suitable inlet points and measuring the temperature distribution at downstream points by means of sensitive thermistor elements. The differential pressure and temperature data are recorded automatically on punched cards which provide the input information for a computer program that automatically analyzes and processes the data.

(7281)

FLOW MODELING STUDIES FOR SODIUM-COOLED REACTORS.

- (d) Experimental.
- (e) In one nuclear reactor flow modeling study, the upper plenum coolant flow was modeled using water as the modeling fluid. Injection of an electrolyte into the water simulated the sudden drop in reactor core outlet temperature following a shutdown. By measuring electrical conductivity as a function of time near the model outlet, data were obtained from which the thermal shock to the outlet nozzle could be inferred. Another flow model was used to study the core flow distribution in the EBR-II reactor. Water was used in this model, also, permitting the free surface of the coolant in the upper plenum to be simulated. The influence of the proximity of the flow passages upon the effective pressure available to the sidewall-facing entrance holes was inferred from flow distribution measurements, permitting adjustment of

the hole sizes to yield the desired flows.

(7822)

DYNAMICS OF ROTATING FLUIDS.

- (e) Oscillation of the free surface of a rotating fluid contained in a cylindrical cavity was investigated. The fluid was assumed to be rotating initially with a Couette-type velocity distribution in a stable configuration. The effects of fill ratio and the initial velocity profile on the frequencies of the subsequent motion were established. The results were of interest in the study of the exterior ballistics of spin-stabilized shells containing non-solid fillers.

(7823)

VISCOUS FLOW WITH MOVING BOUNDARY AND FREE SURFACE.

- (d) Theoretical.
- (e) The practical problem of transporting a lubricating oil by means of a partially immersed rotating wheel led to the development of the theory of viscous streamline flow on a vertical upward-moving surface in the presence of a gravitational field when there is a free surface. The approach used was to equate the shear stress at a point in the liquid, due to the weight of liquid at large distances from the moving solid boundary, to the product of viscosity and velocity gradient. The range of possible values for the thickness of the liquid layer was then determined by the condition that the velocity at the free surface is between zero and the value for which total transport of liquid is a maximum. The rate of transport of liquid was found by integrating the resulting velocity distribution.

GENERAL DYNAMICS CORPORATION, CONVAIR DIVISION, P. O. Box 1128, San Diego, California 22112. R. E. Martin, Chief of Dynamics.

(6294)

MONOGRAPH ON ANALYTIC REVIEW OF LIQUID DYNAMICS IN FIXED AND MOVING CONTAINERS.

- (b) National Aeronautics and Space Administration, Marshall Space Flight Center.
- (d) Theoretical; applied research.
- (e) Monograph, on rigorous mathematical basis, on incompressible liquid sloshing in fixed and moving containers of arbitrary shape. Purpose was to provide foundation for study of propellant sloshing in liquid rockets.
- (f) Completed.
- (h) "Liquid Propellant Sloshing in Mobile Tanks of Arbitrary Shape," D. O. Lomen, NASA CR-222, April 1965. CFS1, Springfield, Va. 22151, \$3.00.

(6295)

MONOGRAPH ON TESTING FOR BOOSTER PROPELLANT SLOSHING PARAMETERS.

- (b) National Aeronautics and Space Admin., Marshall Space Flight Center.
- (d) Monograph on experimental approaches.
- (e) Summarizes modeling laws and test techniques for scale model testing of sloshing of propellant in liquid rockets.
- (f) Completed.
- (h) "Dynamic Stability of Space Vehicles; Vol. XIV - Testing for Booster Propellant Sloshing Parameters," D. M. Eggleston, NASA CR-948, May 1968.

GENERAL DYNAMICS CORPORATION, ELECTRIC BOAT DIVISION, Eastern Point Road, Groton, Connecticut 06340. V. T. Boatwright, Jr., Manager, Research and Development.

(7292)

ESTIMATION OF THE HYDRODYNAMIC STABILITY DERIVATIVES OF SUBMARINES AND SURFACE SHIPS.

- (c) Quentin Wald, Res. Hydrodynamicist.
- (d) Theoretical investigation with practical applications.
- (e) Methods have been developed for the estimation of the stability derivatives of submerged submarines, surfaced submarines, and surface ships. Basic hull contributions are computed by a theoretical strip method modified to account for viscous effects. Effects of appendages are calculated by a previously reported method (6375-HRUS, 1968) which accounts for mutual interaction of appendages and hull. The estimation methods have been programmed for digital computation in order to provide information required in preliminary design studies when experimental information is not available.
- (f) Completed, but may be extended for new requirements.
- (g) Computer programs produce stability derivative values which are usually sufficiently accurate for preliminary design evaluation and trajectory simulation.

(7293)

THE PRESSURE EFFECT ON THE VISCOSITY OF 2110TH (MIL-L-17672) HYDRAULIC FLUID (0-5000 PSI).

- (b) NAVSHIPS contract Nobs 4936A.
- (c) Frank Zambanini and Walter King, Res. and Dev. Test Engrs.
- (d) Primarily experimental investigation of a basic nature with practical applications.
- (e) An experimental program was conducted to establish a relationship with pressure on the viscosity of this petroleum base fluid at various temperatures. Two approaches were used, namely, the falling sphere viscometer method and the laminar flow pressure drop method.
- (f) Completed.
- (g) The report includes both analytical and experimental results. The final results indicate that the viscosity of 2110th hydraulic fluid will increase a minimum of 117% at 30°F and 68% at 100°F, when pressurized to 5000 psig. The report contains graphical data showing the relationship of pressure on viscosity, between 0 psi and 5000 psi, and temperatures between 20° and 140°F.
- (h) "Test Report of the Pressure Effect on the Viscosity of 2110TH Oil (0-5000 psi)," Frank Zambanini and Walter R. King, General Dynamics Corp., Electric Boat Div., Rept. No. U412-69-042, April 22, 1969.

GENERAL ELECTRIC COMPANY, Nuclear Energy Division, Atomic Power Equipment Department, 175 Curtner Ave., San Jose, California 95125. Dr. E. Janssen, Mail Code 583.

(7294)

TWO-PHASE FLOW AND HEAT TRANSFER IN MULTI-ROD GEOMETRIES.

- (b) U. S. Atomic Energy Commission.
- (d) Experimental and theoretical, applied.
- (e) Measurements are being made of both fully developed and developing two-phase upward flow in vertical channels, adiabatic and with heat addition, from which can be determined rates of mass and energy transfer in the transverse direction. Channel

- configurations include circular tube, annulus, and 9-rod (3x3 array) bundle in square shroud. Critical boiling heat flux measurements are also being made. The results will be used to improve present methods for predicting pressure drop and the limits of heat transfer in boiling upward flow in the multirod geometries typical of boiling water reactors.
- (g) Measurement of film thickness for high pressure steam/water in the circular tube, by means of a traversing probe and the McManus criterion for location of interface (probe "sees" liquid 50% of time and vapor 50% of time), shows no difference between thickness under adiabatic conditions and with heat addition (0.55×10^6 Btu/hr ft²). Results are in fair agreement with the results of Bergles, et al. Flow rate in the film region however, as measured isokinetically by means of scoops, is significantly greater under adiabatic conditions than with heat addition. Measurement of subchannel flow in the 9-rod channel, by drawing the flow off isokinetically and passing through a calorimeter shows that the quality (ratio of vapor to liquid flow) in the corner is significantly less than the channel average, contrary to what had been predicted by existing means of subchannel analysis. This is attributed to the strong affinity of the vapor phase for the less restricted higher velocity, center subchannel. The results also show that when transverse flow takes place from one subchannel to another, the quality of the transverse flow is higher than the average of the donor subchannel.
- (h) "A Study of Adiabatic, Fully-Developed, Annular-Dispersed Two-Phase Flow in a Vertical Round Tube," R. L. Simpson, GEAP-10094, Jan. 1969. Available from the Clearing House for Federal Scientific and Technical Information, Natl. Bur. of Standards, U. S. Dept. of Commerce, Springfield, Va.
"Two-Phase Flow and Heat Transfer in Multirod Geometries; Air-Water Flow Structure Data for a Round Tube, Concentric and Eccentric Annulus, and Nine-Rod Bundle," F. A. Schraub, R. C. Simpson, E. Janssen, GEAP-5739, Jan. 1969. Available from same sources as above.
"Subchannel and Pressure Drop Measurements in a Nine-Rod Bundle of Diabatic and Adiabatic Conditions," R. T. Lahey, B. S. Shiralkar, D. W. Radcliffe, GEAP-13049, March 1970. Available from same source as above.
- (7295)
STUDY OF SUBCOOLED BOILING IN TWO-PHASE FLOW.
(c) G. E. Dix, Mail Code 583.
(d) Experimental and theoretical. Basic research for doctoral thesis.
(e) Application of hot-wire anemometer, resistance thermometer, and high speed films to the determination of void fraction profiles, temperature profiles, and condensation rates under subcooled boiling conditions. The work is directed toward the evaluation and improvement of subcooled boiling void fraction predictions.
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- GEORGIA INSTITUTE OF TECHNOLOGY, School of Civil Engineering, Atlanta, Georgia 30332. William M. Sangster, Director, School of Civil Engineering.
- (5545)
ANALYTICAL AND EXPERIMENTAL STUDY OF BED FORMS UNDER WATER WAVES.
- (b) Coastal Engrg. Research Ctr., U.S. Army Corps of Engrs.
(c) Dr. M. R. Carstens.
(d) Theoretical and experimental; basic research which is partly for a doctoral thesis.
(e) Various features of the bed forms which occur with oscillatory flow over a bed of uniform sand were studied experimentally in an oscillatory-flow water tunnel. The amplitude of the water motion was a controlled variable. Three sizes of bed material were used in otherwise similar experiments. The period of oscillation was essentially the same in all runs. A flat bed was the initial condition. Initial and final transients were eliminated from the water motion. The experiments were organized to study (a) incipient motion, (b) evolution of a duned bed, (c) geometry of equilibrium dunes, and (d) drag force of the duned bed on the flow.
(f) Completed.
(h) "Bed Forms Generated in the Laboratory Under an Oscillatory Flow: Analytical and Experimental," M. R. Carstens, F. M. Neilson, and H. D. Altinbilek, TM No. 28, U. S. Army, Corps of Engrs., Coastal Engrg. Res. Center, June 1969, 39 pp. + 24 fig. "The Geometry of Stable Bed Forms Under Oscillatory Flow," F. M. Neilson, Ph.D. Dissertation submitted to the Ga. Inst. of Tech., June 1969, 101 pp. + 27 fig.
- (6686)
TWO-PHASE FLOW IN A VERTICAL BEND.
(b) Office of Water Resources Research and laboratory (matching-fund grant).
(c) Dr. M. R. Carstens.
(d) Experimental; basic research for doctoral thesis.
(e) Two phase flow (air-water) down a vertical conduit, through a 90-degree elbow, and thence through a horizontal conduit is being studied in square conduits. Particular attention is being given to the transition from a bubbly mixture in the vertical leg to stratified (open-channel) or plug flow in the horizontal leg. Flow variables are air concentration and Froude number in the horizontal leg. Geometric variables are radius of curvature of the simple circular bends and length of the horizontal conduit.
(f) Completed.
(h) "A Study of Flow Conditions in Shaft Spillways," Yusuf C. Mussalli and M. R. Carstens, Water Resources Center Rept. WRC 0669, Ga. Inst. of Technology, 158 pp. + 67 fig., Sept. 1969.
- (6687)
LOCALIZED SCOUR.
(b) U.S. Army, Corps of Engrs., Coastal Engrg. Research Ctr.
(c) Dr. M. R. Carstens.
(d) Theoretical and experimental; basic and applied research part of which is being used as a doctoral thesis.
(e) The unsteady phenomenon of localized scour which occurs in the sand bed as the result of non-uniform flow induced by an object placed in a flowing fluid is being analyzed by means of mass-transport relations. The rates of sand transport out of and into the scour-hole and the scour-hole geometry are evaluated separately. The empirically determined functions for the transport functions and the appropriate scour-hole geometric function are substituted into the total differential for scour-hole volume. Integration of the differential equation results in the desired scour depth-time function. The reasons for this approach are (1) division into three

parts, that is, discharge out, discharge in, and scour-hole geometry is more manageable, and (2) the range of model studies is definitely limited by the scale effect of dunes. Experimental studies have been completed for a horizontal cylinder lying on a sand bed under oscillatory flow. Current studies involve localized scour around a single vertical pile protruding into a sand bed under oscillatory flow.

- (f) Completed.
- (h) "Similarity Laws for Localized Scour," Marion R. Carstens, J. Hyd. Div. Proc. ASCE, Vol. 92, No. HY3, pp. 13-36, May 1966.
- "Localized Scour around a Vertical Circular Pile in Oscillatory Flow," H. D. Altimbilek and M. R. Carstens, Final Report Contract No. DACW 72-67-C-0017, U. S. Army, Corps of Engrs., Coastal Engrg. Res. Center, 124 pp. + 34 fig., Oct. 1969.

(6688) DIFFUSION OF PARTICLES BY TURBULENCE - EFFECTS OF PARTICLE SIZE.

- (b) U.S. Dept. of the Interior, Federal Water Pollution Control Admin.
- (c) Dr. M. R. Carstens.
- (d) Experimental.
- (e) A diffusion chamber was constructed in which the turbulence was homogeneous and isotropic in a gross sense. The chamber is cylindrical being 13 inches in diameter by 1-inch in height. Sixty-eight nozzles which are directed vertically downward are arranged in a separating square network with a 1-inch spacing between the rows of 0.190-inch diameter nozzles. Thirty-four nozzles discharge into the chamber while the other thirty-four exhaust from the chamber. An unvalved piston pump is used to force water into and out of the chamber through the nozzles in the roof. The floor of the chamber is plate glass. In the current experiments, six sizes of nylon spheres are placed in the chamber and motion pictures are taken to determine particle motion. The smallest particle is 3/32-inch in diameter and the largest is 1/2-inch in diameter. Amplitude and frequency of the pump are fixed. The data are analyzed in accordance with the theory of continuous movement using coordinates of individual particles as input data.
- (g) The diffusion coefficients and the mixing length of all particles less than 9/32-inch in diameter were the same. If the ratio of particle diameter to mixing length is less than unity, the ratio of particle diffusivity-to-fluid diffusivity is also unity. The particle diffusivity decreases to zero if the ratio of particle diameter to mixing length is about three.
- (h) "Diffusion of Particles: Effect of Particle Size," Hirendra Majumdar and M. R. Carstens, Water Resources Center Rept. WRC 0967, Ga. Inst. of Tech., 102 pp. + 12 fig., Dec. 1967.

(6689) CHARACTERISTICS OF A POSITIVE SURGE IN AN OPEN CHANNEL WITH A CIRCULAR BOTTOM.

- (c) Dr. M. R. Carstens.
- (d) Experimental; basic research for master's thesis.
- (e) A positive surge was created in a horizontal, transparent, 8-inch diameter, plastic pipe. A plane-faced piston at one end of the pipe was moved at a constant velocity in order to generate a surge which progressed over still-water. The single variable in the experiments was still-water depth which, of course, altered the geometry of the cross section. Differential pressure measurements between two stations along the pipe

were used to determine the undular surge profile and celerity. Gross-stream tube analysis (continuity and linear momentum) was verified in every respect. At the smaller depths, the frictional forces were sufficient to have reached an equilibrium water-surface profile at the measuring stations whereas with the larger depths, the profile was changing as the surge moved up the channel.

- (f) Completed.
- (h) "An Investigation of the Small Undular Surge in a Horizontal Channel of Circular Cross Section," James Franklin Adams, M. S. Thesis presented to Ga. Inst. of Technology, 50 pp. + 16 fig., Aug. 1969.

(6690) UNSTEADY OPEN CHANNEL FLOW.

- (c) Dr. C. S. Martin.
- (d) Experimental and theoretical; Ph.D. thesis.
- (e) The equations of motion for unsteady gradually varied open channel flow are expressed in a finite-difference form suitable for programming on a high-speed digital computer. For subcritical flow the theory and computer program were tested and the results compared with existing experimental results corresponding to the following situations: (1) flood hydrograph in circular channel; (2) power load rejection in headrace of trapezoidal canal; (3) power load acceptance in tailrace of rectangular model channel; and (4) tidal (stage) hydrograph in rectangular model estuary. The stability of the finite-difference method was tested for such severe flow situations as the dam break problem. A finite-difference method was also developed for unsteady supercritical flow. The numerical stability and instability of unsteady supercritical flow corresponds somewhat with established criteria based on experiment and analyses. An experiment was conducted in a flume for which a moving hydraulic jump produced both subcritical and supercritical flow in the same channel. A finite-difference scheme was developed that simulated both regimes well.
- (h) "Open-Channel Surge Simulation by Digital Computer," C. Samuel Martin and F. G. De Fazio, J. Hyd. Div., Proc. ASCE, Vol. 95, No. HY6, pp. 2049-2070, Nov. 1969.

(6692) EFFECT OF A PERMEABLE BED ON SEDIMENT TRANSPORT.

- (b) Office of Water Resources Research.
- (c) Dr. C. S. Martin.
- (d) Experimental; basic research.
- (f) Completed.
- (g) The force required to move water through soil is normally called the seepage force and is directly related to the hydraulic gradient. The seepage force on the interfacial sand grains that comprise the bed of a stream or canal is of particular importance as regards its effect on slope instability, incipient motion, and sediment transport. The effective seepage force on cohesionless interfacial bed particles that comprise a plane bed was determined experimentally from the results of slope instability tests and from extrapolation of the results of erosion tests. Using two sand columns as test facilities, one square and the other circular in cross section, the seepage flow was either into or out of the bed for the slope instability tests. For uniform sand particles ranging from 0.46mm to 0.72mm diameter the seepage force on the interfacial sand grains was determined to be one-half the seepage force on particles well within the bed. Erosion of the sand bed was measured for seepage flow vertically upward and

into the bed subsequent to instability of the bed. From an extrapolation of the results of the erosion tests to a condition of zero erosion, which was assumed to correspond to the condition of incipient instability, it is concluded that the seepage force on the interfacial grains is approximately 35 to 40 percent the seepage force on the grains well within the bed.

Incipient-motion tests were conducted with and without seepage. It was found that seepage may either enhance or hinder incipient motion, depending on the relative magnitude of the boundary shear stress and the seepage force, both of which depend upon the seepage flow. For a given hydraulic gradient for seepage into a bed the size of the sand grains is critical regarding incipient motion. Incipient motion may be hindered for smaller sand grains but enhanced for larger sand grains. For the same hydraulic gradient the greater permeability associated with the larger sand grains results in a greater seepage velocity, and a correspondingly greater shear stress. Tests on the effect of seepage on the bed-load carrying capacity of a stream indicated that sediment transport is not measurably impaired by seepage into a bed, unless fine particles of the sand mixture or foreign material are deposited in the bed, resulting in a concreting effect. Tests indicated that seepage flow into a bed in the vicinity of non-uniform flow aids the suspended-load carrying capacity of the stream by inducing strong secondary currents. For practical values of the magnitude of the hydraulic gradient, that is less than unity, the effect of seepage on incipient motion and sediment transport is not expected to be significant, however.

- (h) "The Effect of a Permeable Sand Bed on Sediment Motion," C. Samuel Martin and Mustafa M. Aral, Water Resources Center Rept. WRC-0869, Ga. Inst. of Tech., Nov. 1969, 97 pages.

(6693) SOLUTIONS OF SEEPAGE THROUGH COMPLEX MEDIA BY FINITE ELEMENTS.

- (c) Dr. Paul G. Mayer.
- (d) Theoretical; basic research.
- (e) Seepage through naturally occurring materials frequently requires treatment of media which are seldom isotropic and more often nonhomogeneous. The method of finite elements is a general numerical method by which complicated seepage problems can be effectively conditioned for digital computation.
- (h) "Solution of Anisotropic Seepage by Finite Elements," O. Zienkiewicz and Y. K. Cheung, J. Engrg. Mechanics Div., ASCE Proc., EMI-4676, Feb. 1966, pp. 111-120.
- "Numerical Modelling in Fluid Mechanics," Bruce R. Olmstead, M.S. thesis, Ga. Inst. of Tech., Sept. 1968, 79 pages.

(6694) TAINTER GATES AS FLOW MEASURING DEVICES.

- (b) U.S. Dept. of Agriculture, Agricultural Research Service.
- (c) Dr. Paul G. Mayer.
- (d) Theoretical and experimental; applied research.
- (e) Soil and water conservation practices in the Southern Florida Flatwoods, as elsewhere, have utilized Tainter gates for the purpose of stream flow control. The study of existing control structures in Okeechobee County, Florida, was coupled with hydraulic model studies to enhance the design of Tainter gates, to investigate the

use of such gates as flow measuring devices, to adapt remote sensing devices for the recording of pertinent field data, and to develop computer programs which would translate periodic recordings into discharge rates.

- (f) Completed.
- (h) "Hydraulic Investigation of Tainter Gates as Flow Measuring Devices," WRC Rept. 0168, Water Resources Center, Ga. Inst. of Tech., April 1968, 103 pages.

(6695) UNSTEADY FLOW OF DILUTE AQUEOUS HIGH POLYMER SOLUTIONS IN PIPES.

- (b) Water Resources Center.
- (c) Dr. Paul G. Mayer.
- (d) Theoretical and experimental; basic research.
- (e) Small traces of certain long-chain polymeric molecules, dissolved in water, reduce turbulent friction in flow through pipes. Local additions of polymers will change the resistance characteristics almost instantly, and the progress of the fluid slug with changed properties is a time dependent process. A mathematical study of head and velocity changes is to be carried out using numerical procedures and an electronic digital computer. The mathematical problem is to be formulated as an initial value problem. Solutions to simple pipe problems involve the Runge-Kutta procedures and the Adams-Bashforth method. A laboratory study of unsteady pipe flow is to verify the mathematical model. The mathematical procedures are to be extended to parallel pipe systems and to pipe networks.
- (g) Experiments carried out in a 2-inch diameter pipe demonstrated that a 40 percent reduction resulted from admixture of 100 parts per million by weight. Reductions as much as 60 percent were observed at polymer concentrations of 300 parts per million. The experiments were carried out as steady-state processes. The basic simple pipe unsteady pipe flow problem has been solved numerically. Laboratory experiments are under way to verify the procedures.
- (h) "Unsteady Flow of Aqueous Solution of Long-Chain Polymers in Pipe Networks," H. C. Jackson, M.S. Thesis, Ga. Inst. of Tech., Jan. 1970, 135 pages.
- "Unsteady Flow of Dilute Aqueous Polymer Solutions in Pipe Networks - A Method to Improve Water Distribution," WRC Rept. 0170, Water Resources Center, Ga. Inst. of Tech., Feb. 1970, 139 pages.

(6696) FLOW CHARACTERISTICS OF SPHERES IN DILUTE AQUEOUS HIGH POLYMER SOLUTIONS.

- (c) Dr. Paul G. Mayer.
- (d) Experimental; M.S. thesis.
- (e) The addition of small amounts of certain long-chain polymeric substances to water causes noticeable changes of drag on spheres at certain Reynolds numbers. Glass spheres and steel spheres are used in a study of settling characteristics in tubes containing various concentrations of polymers dissolved in water.
- (h) "Drag of Spheres in Aqueous Solutions of the Long-Chain Polymer Polyhall 295," G. I. Kellman, M.S. thesis, Ga. Inst. of Tech., June 1969, 57 pages.

(6697) TURBULENT FLOW ESTABLISHMENT.

- (b) U.S. Geol. Survey.
- (c) Dr. Paul G. Mayer.
- (d) Experimental and theoretical; M.S. thesis, Ph.D. thesis.

(e) A major assumption made in experimental and in analytical studies of turbulent flow through straight channels and conduits is that the flow is established. The criterion applied to open channel flows is that of constant depth from station to station, and the criterion applied to enclosed conduit flow is that of a constant pressure gradient. Flow establishment is studied as a development of the turbulence power spectrum. Established flow is defined as the equilibrium state between turbulence energy generation and energy dissipation.

(g) The study demonstrated that pressure gradients and constant depths are the least sensitive and accurate criteria for flow establishment. The establishment of constant velocity distributions as measured by pitot tubes were a more sensitive criterion. The intensity and scale of turbulence, as well as the turbulence power spectrum are the superior criteria for flow establishment when mixing, diffusion, heat and mass transfer are to be studied.

(h) "Turbulent Flow in a Three-Dimensional Channel," H. J. Tracy, J. Hyd. Div., ASCE Proc., Vol. 91, HY6, Nov. 1965, p. 9-36.

(6698)

OXYGEN TRANSFER TO WATER DROPLETS.

(d) Theoretical and experimental; M.S. thesis.

(e) The re-aeration of oxygen-deficient streams and lakes is of utmost importance to the full utilization of water resources.

A possible method for obtaining water with relatively high concentrations of dissolved oxygen is that of spraying oxygen-deficient water into a pressurized tank with pure oxygen or with air. The water would fall through the atmosphere, absorbing oxygen as it did so, and collect in a receiving pool from which water could be withdrawn to enrich oxygen-deficient waters. A preliminary theoretical and experimental investigation was conducted with an oxygen atmosphere. A literature survey was made of the basic interphase mass transfer theories. The preliminary experimental study employed a 75-gallon tank into which water was sprayed through whirl-type nozzles. The operating pressures ranged from zero to approximately 10 atmospheres. Oxygen concentrations were measured with galvanic oxygen analyzers. For the pressures applied, a fifteen-fold increase in dissolved oxygen concentration could be obtained.

The present work is carried out with compressed air in an improved reactor. It is proposed to study the cost-efficiency of the method in its application to oxygen-deficient streams and lakes.

(g) The experimental time-average transfer coefficient was similar to that predicted by both the circulating and the turbulent droplet models.

(h) "A Preliminary Investigation of Oxygen Transfer to Liquid Drops Produced in a Spray in a Gaseous Medium," M. A. Collins, M. S. thesis, Ga., Inst., of Tech., Dec. 1967, 301 pages.

(6699)

DYNAMIC RESPONSE FUNCTIONS OF OCEAN STRUCTURES.

(c) Dr. Paul G. Mayer.

(d) Theoretical; Ph.D. thesis.

(e) The object of the study is to develop a technique for analyzing the dynamic response of off-shore structures subjected to random wave forces and to the constraints imposed by the foundation medium of the ocean floor. Emphasis is placed on the use of existing models of the forcing functions and the restraining functions to for-

mulate a numerical method analysis.

The structural model is analyzed for free and random vibrations. Cross-power spectra are developed for random force fields and random wave heights. Consideration is given to fluid damping and the effects of vortex shedding. Dynamic resistance of soils to the movements of piles is to be included. The finite element method may be used in the analysis of dynamic foundation response.

(h) "A Stochastic Model for the Response of Permanent Offshore Structures Subject to Soil Restraints and Wave Forces," B. L. Edge, Ph.D. thesis, Ga., Inst. of Tech., July 1968, 204 pages.

"A Stochastic Model for the Response of Permanent Offshore Structures Subject to Soil Restraints and Wave Forces," WRC Report 0269, Water Resources Center, Ga. Inst. of Tech., April 1969, 203 pages. "A Dynamic Structure-Soil-Wave Model for Deep Water," ASCE Ocean Engrg. Conf. II, Miami, Fla., Dec. 1969, 23 pages.

(7296)

INCIPIENT MOTION.

(c) Dr. M. R. Carstens.

(d) Experimental; basic research for doctoral dissertation.

(e) Incipient-motion conditions of 1-in. diameter spheres in an air stream are being studied. Equipment and instrumentation has been designed so that the effects of (a) angle of repose, (b) protrusion from the bed, and (c) approach-velocity distribution can be determined independently. Incipient-motion conditions are being defined by probability of occurrence.

(7297)

LOW-SPEED CAPSULE-TRANSPORT PIPELINES.

(c) Dr. M. R. Carstens.

(d) Experimental and theoretical.

(e) Low-speed capsule-transport pipeline systems are being investigated. A through-flow booster pump has been invented and has been extensively studied. Unstreamlined wheeled vehicles have been designed and have been model-tested in order to determine the drag characteristics. A mathematical model of the system has been formulated and can be solved numerically for the determination of the kinematic variables (displacement, velocity, and acceleration) as a function of time for each vehicle (capsule) in the pipeline. The object of the project is to develop the engineering capability for the design of low-speed capsule-transport pipelines in order that such systems can be assessed as a transportation system in a given situation.

(7298)

AIR ENTRAINMENT IN ENCLOSED CONDUITS.

(c) Dr. C. S. Martin.

(d) Experimental; basic and applied research.

(e) The formation of hydraulic jumps in sloping conduits and the transition from bubbly flow to slug flow in a vertical shaft are currently being studied. Model studies were conducted on an outfall line for the purpose of removing air entrained by moving hydraulic jumps. Air was removed by using simulated air release valves. Entrainment of air into vertical shaft through Borda type entrances is being studied. Air demand at inlet is measured. Instability of nappe and resultant pressure fluctuations and vibrations are being measured and studied. Formation of slug flow and subsequent blow back or blow out is also being studied.

(h) "Hydraulic Model Studies of Natchez Mill Outfall,"

(7299)

WIND FORCES ON STRUCTURES.

- (c) Dr. Paul G. Mayer.
- (d) Theoretical and experimental.
- (e) Dynamic loading on buildings due to wind velocities and pressures result in strain in structural members and in overall building drift. Attempts are made to obtain measurements of wind loads on a high-rise building and observe the structural responses.

(7300)

TRANSPORT CHARACTERISTICS OF LOG-NORMAL DISTRIBUTED BED MATERIALS IN OPEN CHANNELS.

- (c) Dr. Paul G. Mayer.
- (d) Theoretical and experimental; Ph.D. thesis.
- (e) Information is sought on the interaction of the turbulence structure in open channel flow and the bed load movement of log-normally distributed bed materials. Time-dependent measurements are made of sediment transport and size distributions. Turbulence measurements are made with a constant temperature hot-film anemometer. The phenomenon of armoring is investigated.

(7301)

EVALUATION OF DESIGN METHODS OF SUBSURFACE DRAINAGE FACILITIES FOR HIGHWAYS.

- (b) State Highway Dept. of Georgia, and Federal Highway Administration.
- (c) Dr. George M. Slaughter.
- (d) Theoretical and field investigation; applied research and design.
- (e) The purpose is to evaluate the design methods and construction procedures currently used on the drainage facilities designed for the removal of subsurface waters (regardless of origin) from the immediate vicinity of the highways. The scope of the project consists of determining the origin of the existing methods as used in Georgia; finding out what has been and is being done elsewhere; evaluating the effectiveness of current design methods used in Georgia; recommending appropriate changes where necessary; and determining the feasibility and need for further studies in this area.

GEORGIA INSTITUTE OF TECHNOLOGY, School of Engineering Science and Mechanics, Atlanta, Georgia 30332. Milton E. Raville, Director, School of Engrg. Science & Mechanics.

(7302)

HYDROELASTIC OSCILLATIONS IN UPRIGHT CIRCULAR CYLINDER.

- (c) Dr. Helmut F. Bauer.
- (d) Theoretical; applied research.
- (e) Behavior of incompressible and nonviscous liquid with free surface in an upright circular cylindrical container is treated. Free and forced oscillation with arbitrary wall- and bottom excitation is covered and determination of coupled frequencies of liquid-structure system for elastic bottom and wall (shell equations) is indicated.
- (f) Completed.
- (h) "Hydroelastische Schwingungen im aufrechten Kreiszylinderbehälter," H. F. Bauer, Zeitschrift für Flugwissenschaften (accepted).

(7303)

LINEAR HYDROELASTIC SLOSHING.

- (c) Dr. Helmut F. Bauer, Dr. Julius Siekmann.
- (d) Theoretical, applied research.
- (e) Axisymmetric hydroelastic oscillations of a liquid with free surface is treated with elastic bottom and rigid wall, or elastic wall and rigid bottom. Forces and moments are determined. Some remarks are made about the approximate investigation of oscillations under weak gravity.
- (f) Completed.
- (h) "Note on Hydroelastic Sloshing," H. F. Bauer and J. Siekmann, ZAMM 49, 10, pp. 577-589 (1969).

(7304)

DYNAMIC INTERACTION OF A LIQUID WITH THE ELASTIC STRUCTURE OF A CIRCULAR CYLINDRICAL CONTAINER.

- (c) Dr. Helmut F. Bauer, Dr. Julius Siekmann.
- (d) Theoretical; applied research.
- (e) Investigates the general case of hydroelastic coupled oscillation of a partially filled liquid container with flexible bottom and an elastic sidewall (Donnell's equation). Bottom is either flexible membrane or thin elastic plate.
- (f) Completed.

(7305)

FLUID BEHAVIOR IN A LONGITUDINALLY EXCITED CYLINDRICAL TANK OF ARBITRARY SECTOR-ANNULAR CROSS-SECTION.

- (b) NASA-Institutional Grant.
- (c) Dr. Helmut F. Bauer and Dr. J. Woodward, (Bauer: School of Engineering Science and Mechanics, Georgia Inst. of Tech., and Woodward: University of Alabama in Birmingham, Birmingham, Ala.)
- (d) Theoretical; applied research, thesis.
- (e) Response of liquid free surface motion is presented for a longitudinally excited container with annular circular sector cross section. Depending on the excitation parameters, the free surface will remain a plane or oscillate with a finite amplitude. The finite amplitude motion can be subharmonic, harmonic or superharmonic. The importance of the harmonic and superharmonic is considerably lessened because of stability considerations. Forces and moments are obtained.
- (f) Completed.
- (h) "Fluid Behavior in a Longitudinally Excited Cylindrical Tank of Arbitrary Sector-Annular Cross Section," H. F. Bauer and J. T. S. Wang, AIAA J. (acc.).

(7306)

AXISYMMETRIC HYDROELASTIC SLOSHING IN AN ANNULAR CYLINDRICAL CONTAINER WITH ELASTIC WALLS.

- (c) Dr. Helmut F. Bauer, Dr. Julius Siekmann, Dr. J. T. S. Wang.
- (d) Theoretical, applied research.
- (e) Coupled axisymmetric frequencies for liquid with free surface in a cylindrical container with annular cross section are determined.
- (f) Completed.
- (h) "Axisymmetric Hydroelastic Sloshing in an Annular Cylindrical Container with Elastic Walls," H. F. Bauer, J. Siekmann, J. T. S. Wang, J. Spacecraft and Rockets, Vol. 5, No. 8, pp. 981-983 (1968).

(7307)

DYNAMICS OF PROPELLANT IN A SPINNING CONTAINER AND DESCRIPTION BY A MECHANICAL MODEL.

- (b) Dept. of the Army, and Army Missile Command, Redstone Arsenal, Alabama.
- (c) Dr. Helmut F. Bauer, S. S. Chang.
- (d) Theoretical; applied research.
- (e) Behavior of liquid with free surface in uniformly spinning annular container is investigated. Free

- and forced oscillations for small and large angular speeds are presented. Also a mechanical model is suggested and derived.
- (f) Completed.
- (h) "Dynamics of Propellant in a Spinning Container and Description by a Mechanical Model," Final Report, Georgia Inst. of Tech., Contract No. DAAH01 (Nov. 69) pp. 1-150.

(7308)
THEORETICAL INVESTIGATION OF GAS MANAGEMENT IN ZERO-GRAVITY SPACE MANUFACTURING.

- (b) NASA, Marshall Space Flight Center, Huntsville, Alabama.
- (c) Dr. Helmut F. Bauer.
- (d) Theoretical; applied research.
- (e) Behavior of spinning liquid-gas-system under zero-gravity; determination of geometrical shape and location of globe and gas bubble as function of surface tension, chamber pressure, rotational speed and volumes migration of gas bubble.

UNIVERSITY OF HAWAII, Department of Civil Engineering,
2565 The Mall, Honolulu, Hawaii 96822. Dr. John A. Williams, Associate Professor.

(6155)
LAMINAR, RADIAL FLOW OF A VISCOUS FLUID BETWEEN PARALLEL PLATES.

- (d) Theoretical and experimental; basic research.
- (e) The purpose of the investigation is to study the effects of the convective acceleration on the velocity profile of a radial flow and the stability of such a profile.
- (f) Project discontinued.

(7309)
MODEL STUDIES OF TIDAL EFFECTS ON GROUND WATER HYDRAULICS.

- (b) Water Resources Research Center.
- (d) Experimental and theoretical, applied research.
- (e) Hydraulic, electric analog, and mathematical models were used to study the response to tidal changes of aquifers in communication with the sea. Both confined and unconfined homogeneous and isotropic aquifers of simple boundary geometry were considered. Emphasis was placed on the determination of aquifer properties from observed responses to tidal fluctuations.
- (f) Completed.
- (g) Results indicate that both diffusion theory and the electric analog model can be used to describe the propagation of tidal-induced fluctuations through a porous media, provided that the diffusion coefficients account for capillary rise in unconfined aquifers and for changes in the compressibility of the media in confined aquifers.
- (h) The results are compiled in a report which is currently being prepared for distribution by the WRRC of the University of Hawaii.

(7310)
ANALOG SIMULATION OF TIDAL EFFECTS ON GROUND WATER AQUIFERS.

- (b) Water Resources Research Center.
- (d) Experimental and theoretical, applied research.
- (e) This project is essentially a continuation of (7309). The response to tidal changes of semi-infinite aquifers having discontinuous changes in permeability and average depth and of finite aquifers with linearly varying permeabilities are to be studied. Determination of aquifer properties from observed responses to tidal fluctuations is the basic goal of the study.

tuations is the basic goal of the study.

(7311)
LABORATORY STUDY OF THE RUN-UP OF A DOUBLE-HUMPED WAVE IMPINGING ON A PLANE, SLOPING BEACH.

- (b) Conducted as part of the Joint Tsunami Research Effort, Hawaii Institute of Geophysics, under the direction of Drs. William M. Adams and Gaylord Miller. The large scale experiments are being carried out at the Look Laboratory for Oceanographical Engrg., Dept. of Ocean Engrg., Univ. of Hawaii, Mr. J. T. O'Brien, Lab. Director.
- (d) Experimental-basic research.
- (e) The object of these tests is to validate the numerical predictions of wave runup by J. P. Butler (HIG Report 67-16, Aug. 1967) which are based on a theoretical analysis by Carrier and Greenspan (JFM, 4, 97, 1958). A wave generator, composed of a series of evenly spaced solid strips with their bottom edges contoured to the inverse of the desired double-humped profile, was dropped into the water in such a way that the leading edge of the wave generator coincided with the beach. Two-wire resistance probes located between two adjacent strips of the generator recorded the water surface as the resulting "humps" of water propagated into the beach.
- (g) Initial tests with a small scale generator (i.e., total length 5', strip width 1/4", strip spacing 15/16", maximum crest height 0.53") indicated that a wave of the desired shape, which essentially met the required initial conditions, could be generated. The runup took place in a shorter time scale than predicted with amplitudes less than predicted.
- (h) Results on preliminary tests are available in a paper by John A. Williams and Jan M. Jordaan, Jr., "A Laboratory Study of a Double-Humped Wave Impinging on a Plane Sloping Beach," Proc. Intl. Symp. on Tsunami and Tsunami Research, now in press.

UNIVERSITY OF HAWAII, J. K. K. Look Laboratory of Oceanographic Engineering, Department of Ocean Engineering, 811 Olomehane Street, Honolulu, Hawaii 96813. John Thomas O'Brien, Director of Laboratory.

- (5896)
TSUNAMI RUN-UP AROUND COASTLINE OF OAHU, HAWAII.
- (b) Hawaii Inst. of Geophysics; funded by National Science Foundation.
- (c) William M. Adams, Director, Tsunami Research Group.
- (d) Experimental, model and field data; basic research.
- (e) Determination of wave amplification and run-up potential of tsunamis arriving from various directions at points around Oahu on 1:20,000 and 1:250,000 scale models, undistorted.
- (f) Completed.
- (g) Light-reflection technique devised to show low-steepness wave motion on screen in background of model. Strain gage wave sensors resolve scaled-down tsunamis of amplitudes down to 0.1 mm.
- (h) "Model Study of Tsunami Amplification around the Island of Oahu, Hawaii," W. M. Adams and J. M. Jordaan, (TR-6 J.K.K. Look Lab.) Center for Engrg. Research, Univ. of Hawaii, Honolulu, 1968.
- "Tsunami Height, Oahu, Hawaii: Model and Nature," W. M. Adams and J. M. Jordaan, Proc. 11th Conf. on Coastal Engrg., London, Sept. 1968. Page 1555, Chapter 100.

- (6073)
BARBERS POINT HARBOR MODEL STUDY.
 (b) U.S. Army Corps of Engrs., Honolulu District.
 (c) Howard Harrenstien, Director, Center for Engrg. Research.
 (d) Experimental; model and analytic data; applied research.
 (e) Determination of optimum design of deep-draft and small-boat harbors at Barbers Point, Oahu. Model is to 1:100 scale, undistorted, equipped with variable direction, period and amplitude wave generators.
 (f) Completed.
 (g) Modified harbor plans recommended.
 (h) "Study of Proposed Barbers Point Harbor, Hawaii," (TR-8 J.K.K. Look Lab) Center for Engrg. Research, Univ. of Hawaii, Honolulu, 1970.

- (6074)
KUHIO BEACH MODEL STUDY (WAIKIKI).
 (b) State of Hawaii, Dept. of Transportation, Harbors Div., Honolulu, Hawaii.
 (c) R. Q. Palmer, Consultant, Univ. of Hawaii.
 (d) Experimental and field data; applied research.
 (e) Determination of optimum beach alignment and protection for Kuhio Beach Section, Waikiki Beach, Oahu.
 (f) Completed.
 (g) Beach alignment parallel to refracted wave crests recommended.
 (h) "The Kuhio Beach Model," R. Q. Palmer and T. D. Krishna Kartha, (TR-2 J.K.K. Look Lab.) Center for Engrg. Research, Univ. of Hawaii, Honolulu, Dec. 1966.

- (6075)
WAVE FORCES ON SUBMERGED SPHERES.
 (c) R. A. Grace, Asst. Prof. of Civil Engrg.
 (d) Field installation on foreshore; basic research for Master's thesis.
 (e) To obtain inertial and drag coefficients for submerged spheres subjected to shallow water wave action.
 (f) Suspended.
 (g) Calculated drag coefficients have mean of about 0.7 and range of 0.30 to 1.05 depending upon method of determination; one drag coefficient could be used with third-order theory to predict peak-to-peak total force ranges for waves encountered with average absolute residual of about 13%.
 (h) "An Experimental, Pilot Study of Ocean Wave-Induced Forces on a Bottom-Mounted Sphere," R. A. Grace and F. M. Casciano, (TR-4 J.K.K. Look Lab) Center for Engrg. Research, Univ. of Hawaii, Honolulu, Rept. No. PAC6829, June, 1968.
 "Ocean Wave Forces on a Subsurface Sphere," R. A. Grace and F. M. Casciano, J. Waterways and Harbors Div., ASCE, Vol. 95, No. WW3, Aug. 1969, Paper 6722.

- (7312)
TAN MY CHANNEL STUDY.
 (b) Tan My Channel Model Study, Hue, RVN contract N63185-69-G-0089.
 (c) Officer-in-charge of Construction, Republic of Vietnam, Naval Facilities Engrg. Comm.
 (d) T. T. Lee, Assoc. Researcher.
 (e) Investigation by use of hydraulic model (both three- and two-dimensional) of means to stabilize the entrance to an estuary toward improving it as a ship channel.
 (g) A rigid bed covered with fine sands or ground walnut shells 1/250 horizontal 1/50 vertical scale hydraulic model of a 5 x 3 mile ocean-estuary-land

area near Hue in Vietnam is being operated with objective of determining the most effective means of reducing sediment deposition (shoaling) in the estuary entrance caused notably by action of typhoons featuring 5 ft/5 second NE (downcoast) waves.

- (f) Completed.
 (h) A full length conventional jetty along the up-coast edge of the existing channel seems most effective; a weir-type jetty in the same location may have potential.
 "Model Investigation to Improve the Stability of Tan My Channel, Hue, Republic of Vietnam," T. T. Lee, TR-10 J.K.K. Look Lab of Oceanographic Engrg., Univ. of Hawaii, Feb. 1970 (2 vols.).

- (7313)
CHARACTERISTICS OF WIND-WAVES GENERATED IN THE LABORATORY.
 (c) T. T. Lee, Assoc. Researcher, Dept. of Ocean Engrg.
 (d) Experimental; basic research.
 (e) Investigate the generation of wind waves in laboratory.
 (f) Completed.
 (g) About +20% correction required to the significant wave height predicted by Tucker and Draper simplified method when wave spectral width parameter $(Q/c)^2 = 1 - (T_c/T_z)^2$ is 0.25 to 0.50 (Narrow); the prediction good for width of 0.70. T_c and T_z are wave crest period and cross period respectively. The experimental results compared well with Hino theory for both wave height and wave period and fair with Bretschneider's Fitch graph for wave heights.
 (h) "The Characteristics of Wind Waves Generated in the Laboratory," Proc. 11th Intl. Conf. on Coastal Engrg., Am. Soc. of Civil Engrs., 1968.

- (7314)
LABORATORY STUDIES OF A DISCONTINUOUS WAVE ABSORBER.
 (c) Anthony R. Fallon, Jr. Researcher, Dept. of Ocean Engrg.
 (d) Experimental data; basic research for Master's thesis.
 (e) Investigation of reflection of waves from a wave absorber section with a lower impervious slope and an upper pervious (stone-filled) slope. Tests conducted in 48-ft. long x 9-inch wide flume with 4-inch water depth. Parameters varied were upper slope, lower slope, berm length, depth of discontinuity, wave height and wave length.
 (f) Completed.
 (g) For all test conditions a minimum of reflection was found when the depth of the discontinuity was from one-third to one-half the water depth.

- (7315)
ESTIMATION OF OCEAN WAVE-INDUCED PARTICLE VELOCITIES FROM THE TIME HISTORY OF A BOTTOM MOUNTED PRESSURE TRANSDUCER.
 (c) J. R. Walker, Jr. Researcher, Dept. of Ocean Engrg.
 (d) Master's thesis; field investigation.
 (e) A deterministic and probabilistic comparison of measured and predicted horizontal wave velocities in shallow water.
 (f) Completed.
 (g) Under conditions tested, Airy theory appears to be more reliable in predicting the horizontal wave velocities than higher order theories.

- (7316)
REEF RUNWAY MODEL STUDY.
 (b) Dept. of Transportation, State of Hawaii.
 (c) R. Q. Palmer; R. A. Grace; and J. R. Walker.
 (d) Model study.

- (e) Study of interaction of proposed reef runway off Honolulu International Airport and ocean regime including runup of storm and tsunami waves, effect of tides and currents, pertinent littoral processes, and probability of pollution. A model 70 x 100 feet with scale 1/200 vertical and 1/600 horizontal is used for interaction tests in general. A wave flume 180 feet long and 4 feet wide with plunger generator is used for detailed tests of stability of and runup on sections of protective rubble mound dike.
- (f) 75% complete.
- (g) Water depth controls the wave height, including the maximum, at the toe of the dike. The dike design should be based on maximum wave height possibly slightly seaward of the dike toe.
- (h) "Reef Runway Hydraulic Model Study; Honolulu International Airport," TR-5 J.K.K. Look Laboratory; U. of Hawaii (4 parts). Part 1: "Three-Dimensional Storm Wave Study," J. R. Walker, Sept. 1969.

HYDRONAUTICS, INCORPORATED, Pindell School Road, Howard County, Laurel, Maryland 20810. Mr. Phillip Eisenberg, President.

(7825)

RAIN EROSION.

- (b) Naval Air Systems Command, Dept. of the Navy.
- (c) Andrew Conn.
- (d) Theoretical and experiments; basic research.
- (e) This program is an investigation of the basic dynamic properties of rain erosion resistant coatings, and how these properties may be related to the ability of coatings to withstand damage by high speed impact with raindrops, and provide protection for substrate materials. The purpose of this program is to ultimately develop design criteria for future coating systems and provide guidance in the development of new coating materials.
- (g) The results obtained during the first two phases of this program include: construction and calibration of a split Hopkinson pressure bar facility for measuring stress-strain properties of materials at strain rates up to 10^4 sec^{-1} , and temperatures of over 500°F ; measurements of the properties of a variety of materials, including metals, rigid plastics, and elastomers such as neoprene and polyurethanes; application of these property measurements to predict the fracture and erosion observations made by investigators in the field.
- (h) "Research on Dynamic Response and Adhesion Failures of Rain Erosion Resistant Coatings," A. F. Conn, HYDRONAUTICS, Incorporated, Tech. Rept. 811-1, Jan. 1969.
"Dynamic Response and Adhesion Failures of Rain Erosion Resistant Coatings," A. F. Conn and A. Thiruvengadam, HYDRONAUTICS, Incorporated; presented at Symp. on the Characterization and Determination of Erosion Resistance, ASTM Annual Meeting, Atlantic City, New Jersey, June 1969 (to be published in J. Materials, Sept. 1970).
"Relating Dynamic Properties of Materials and Resistance to Damage by Rain Impact," A. F. Conn, HYDRONAUTICS, Incorporated, Tech. Rept. 905-1, Jan. 1970.

(7826)

EROSION BY LIQUID IMPACT.

- (b) NASA.
- (c) Andrew Conn.
- (d) Theoretical and experiments; basic research.

- (e) The response of metals to repeated liquid impact is being studied under this program. Controlled water impact experiments were conducted in a rotating disk facility, and the observed erosion phenomena were analyzed and compared with erosion theories which were developed. The purpose of these studies is to gain an understanding of the mechanism, and to provide quantitative evaluation of the phenomenon of multiple liquid impact erosion as encountered in systems, such as wet steam or vapor turbines, and in rain erosion of missiles and aircraft.
- (g) Systematic experimental and analytical studies of four metals have been completed: 1100-0 aluminum, 316 stainless steel, commercially pure annealed nickel, and annealed 6 Al-4V titanium. It has been found that the peak rate of erosion varies approximately as the fifth power of the velocity, while the time at which the peak rate is observed varies as the one-fifth power. The observed erosion data have been compared with a recently developed theory of erosion and with fatigue life measurements.
- (h) "Experimental and Analytical Investigations on Multiple Liquid Impact Erosion," A. Thiruvengadam and S. L. Rudy, HYDRONAUTICS, Incorporated, Tech. Rept. 719-1, June 1968 (also NASA Contractor Report CR-1288, March 1969).
"Experimental and Analytical Investigations on Multiple Liquid Impact Erosion," A. Thiruvengadam, S. L. Rudy and M. Gunasekaran, HYDRONAUTICS, Incorporated, Tech. Rept. 719-2, Aug. 1969 (also to be published in J. Materials, Sept. 1970); presented at Symp. on the Characterization and Determination of Erosion Resistance, ASTM Annual Meeting, Atlantic City, New Jersey, June 1969.

(7827)

TURBIDITY CURRENTS.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Sidney Reed.
- (d) Theoretical and experimental; basic research.
- (e) The objectives of this study are to simulate the generation and motion of turbidity currents as they occur in nature, and to develop a theory of the behavior of such currents as these may occur in nature.
Measurements have been made of the parameters which govern the motion of a suspension current velocity, initial excess density, erosion and deposition, and current dimensions.
The experiments were carried out in an 18' lucite tank which has in it a variable slope that can be adjusted from 0° to 16° . The suspension currents were generated by releasing a mixture of clay and water from a source chamber at the top of the slope.
- (g) For the same slope, initial densities and height of fluid in this mixing chamber, velocities of density currents and of clay suspension currents moving on a clean bed were very nearly the same. Slugs of suspension flowing on a pre-deposited clay bed for density excess < 0.04 and above a slope of about 7° were observed to lift clay into suspension and thereby accelerate. Scouring was found to decrease for slugs of higher densities. At a slope of 7° , the velocity of the clay suspension would appear to reach a constant value.
- (h) "Laboratory Results of Salt Water Intrusion," J. Wu, HYDRONAUTICS, Incorporated, Proc. Amer. Soc. of Civil Engrs., Vol. 95, No. HY6, Nov. 1969.
"Density Surge Flow Down an Inclined Plane," W. Van de Watering and J. Shwartz, Amer. Soc. Civil Engrg. Natl. Water Resources Engrg. Meeting, Memphis, Tenn., Jan. 1970.
"Turbidity Currents on Inclined Planes," I. Landau

and J. Schwartz, HYDRONAUTICS, Incorporated, Amer. Geophys. Union 51st Annual Meeting, Washington, D. C., April 1970.
 "Theoretical and Experimental Studies on Density Currents," J. Schwartz, I. Landa, and W. P. M. Van de Watering, HYDRONAUTICS, Incorporated, Tech. Rept. 805-1 (in preparation).

(7828)

REVERSE OSMOSIS MEMBRANES.

- (b) Office of Saline Water, Dept. of the Interior.
- (c) Sidney G. Reed.
- (d) Theoretical and experimental; basic research.
- (e) The characterization of reverse osmosis membranes by the determination of a number of material transport coefficients, which are derived from fundamental phenomenological coefficients. The transport of each component of a solution, through the membrane, is measured independently, under conditions where polarization is minimized. It is hoped in this way to relate performance, preparation technique, membrane chemical and physical properties in order to predict operational behavior and "design" membranes for specific application. The study of membrane formation mechanism is an integral part of this research.
- (g) Solvent and solute transport coefficients, and the "Sigma" coefficient (a measure of membrane salt re-rejection characteristics) have been measured and related to some aspect of membrane fabrications. The kinetics of membrane formation have been studied and certain predictions made possible on the membrane morphology with various polymers and solvents.
- (h) "The Mechanism of Formation of Skinned Type Membranes" - O.S.W. R&D No. 499 (April 1970), and also R. Bloch and M.A. Frommer, Desalination 7(2), 259, (1970), HYDRONAUTICS, Incorporated Tech. Rept. No. 725

(7829)

PROPERTIES OF WATER IN CAPILLARY SYSTEMS.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Sidney Reed.
- (d) Theoretical and experimental; basic research.
- (e) The study of water imbibed in the capillary system of controlled porosity cellulose acetate and other polymer membranes is expected to eliminate some of the possible influences affecting the measurement in silica capillary systems. Measurements of water properties, such as density, vapor pressure, diffusion coefficients and surface tension, and structural properties by nuclear magnetic resonance, are expected to show up differences, if any, between bulk water and that condensed into capillary systems such as described.

UNIVERSITY OF IDAHO, Engineering Experiment Station,
 Moscow, Idaho 83843. Richard E. Warner, Associate Director, Engineering Experiment Station.

For summaries of the following, see Water Resources Research Catalog No. 4:

(102W)

EFFECT OF PHYSICAL PROPERTIES OF POROUS MEDIA ON WATER MOVEMENT, 2.0391.

(103W)

TEMPORAL, HORIZONTAL, AND VERTICAL VARIABILITY OF WATER CHEMISTRY IN THE UNSATURATED ZONE OF FINE GRAINED SOILS, 2.0400.

(104W)

INVESTIGATION OF SEEPAGE REDUCTION BY NATURAL PROCESSES IN IRRIGATION CANALS, 3.0207.

(105W)

INVESTIGATIONS OF CULVERTS AND HYDRAULIC STRUCTURES USED FOR FISHWAYS AND THE ENHANCEMENT OF FISH HABITAT (to be listed in WRRC).

(5897)

FACTORS INFLUENCING THE FLOW OF SUBSOIL WATER IN THE IMMEDIATE PROXIMITY OF AND INTO DRAINAGE FACILITIES.

- (b) Western Regional Research Project.
- (c) Prof. D. W. Fitzsimmons, Agric. Engrg. Dept.
- (d) Experimental; basic.
- (e) To determine relationships between the hydraulic properties of disturbed and undisturbed soil samples.
- (g) Desaturation data have been obtained for several disturbed and undisturbed soil samples. When the data are scaled, the resulting dimensionless desaturation-capillary pressure relationships for the disturbed and undisturbed samples of a particular soil are essentially the same. This is an indication that it may be possible to predict the hydraulic properties of an undisturbed soil by measuring the properties of samples of the soil in the laboratory.
- (h) An M.S. Thesis will be completed in 1970.

(5898)

TWO- AND THREE-DIMENSIONAL DIFFUSION ANALYSIS OF UNSTEADY FLOW INTO POROUS MEDIA.

- (c) Prof. D. W. Fitzsimmons, Agric. Engrg. Dept.
- (d) Experimental; basic.
- (e) To determine quantity and rates of advance of flow into partially saturated porous materials.
- (g) A mathematical model of unsteady radial flow from a cylindrical source into partially saturated porous media has been formulated. The model has been used, in conjunction with a digital computer, to simulate imbibition from a finite-sized cylindrical source. Some of the more significant results include: (1) the inlet boundary condition has a very marked effect on unsteady radial flow from a cylindrical source, (2) the cumulative inflow into a two-dimensional flow system is not a simple exponential function of time as suggested by other investigators. The rate decreases monotonically with time throughout the duration of the inflow process.
- (h) "Using a Tensiometer-Pressure Transducer Apparatus to Study One- and Two-Dimensional Imbibition," N. C. Young, unpublished M.S. Thesis, Univ. of Idaho, 1968.

(5903)

EFFECT OF EXTERNAL AIR PRESSURE ON LIQUID FLOW THROUGH POROUS MEDIA.

- (c) Prof. D. W. Fitzsimmons, Agric. Engrg. Dept.
- (d) Experimental and theoretical; basic research.
- (e) To determine the effect of external air pressure on the flow of liquid through a partially saturated porous material.
- (f) Completed.
- (g) The effects of external air pressure changes on the liquid content, entrapped air content and permeability of two porous media were experimentally determined.
- (h) "Effect of External Air Pressure on Hydraulic Properties of a Partially Saturated Porous Medium," Shen-Tseh Chen, unpublished M.S. Thesis, Univ. of Idaho, 1969.

(6701)

INVESTIGATION OF METHODS FOR AUTOMATIC MEASUREMENT OF SNOW WATER.

- (b) U.S. Army Corps of Engrs.

- (c) V. E. Penton, Asst. Prof., Mech. Engrg. Dept.
- (d) Experimental; development work for M.S. thesis.
- (e) One portion of the project involves measuring the runoff from snow pillows since this would give a measure of the rate of snow melt. Various designs for the snow pillow will be investigated. Another part of the project involves investigation of a diurnal fluctuation in snow pillow readings which often occurs.
- (f) Discontinued.
- (h) "Experience with the Pressure Pillow as a Snow Measuring Device," V. E. Penton and A. C. Robertson, Water Resources Res., Vol. 3, No. 2, pp. 405-408, 1967.

(6702)

A STUDY OF VECTOPLUVIOMETERS.

- (b) Agricultural Research Service, U.S. Dept. Agric.
- (c) V. E. Penton, Asst. Prof., Mech. Engrg. Dept.
- (d) Experimental; development work for an M.S. thesis.
- (e) The objective is to develop a device to measure the horizontal component of wind blown snow, to help in the determination of the vertical component.
- (f) Discontinued.
- (g) Catch efficiencies for various designs have been determined for sawdust in a laboratory wind tunnel.

(6704)

AGRICULTURAL WATER NEEDS FOR THE STATE OF IDAHO.

- (b) Idaho Water Resources Board.
- (c) Dr. G. L. Corey; Chairman, Dept. of Agric. Engrg.
- (d) Field investigation; operation; for M.S. thesis.
- (e) The monthly consumptive use values for 12 crops at 43 weather stations in Idaho were determined by the modified Blaney-Criddle method.
- (f) Completed.
- (h) "Consumptive Irrigation Requirement for Crops in Idaho," Sutter and Corey, Ag. Exp. Sta. Bull. 1970.

(6705)

PRELIMINARY INVENTORY OF THE WATER RESOURCES FOR THE STATE OF IDAHO.

- (b) Idaho Water Resources Board.
- (c) J. J. Peebles, Assoc. Prof., Civil Engrg. Dept.
- (d) Field investigation; operation.
- (e) To provide base information for water resource development of the state.
- (f) Completed.
- (g) Measurements on precipitation maps indicate that the average annual volume of precipitation on the State of Idaho is 99,967,000 acre-feet. Of this amount, water yield maps show that 37,581,000 acre-feet is generated as stream runoff within the boundaries of the State. Approximately 23,100,000 acre-feet of water is diverted or pumped annually to irrigate 3,550,000 acres of land. Of the total water diverted, 6,100,000 acre-feet is used consumptively by the plants. To generate power at developed sites in the State, 97,000,000 acre-feet of water is required, which involves reuse of the same water numerous times. Of Idaho's 562,600 acres of water area, 278,000 acres are available for recreation activities within a 50-mile radius of the six major population centers.
- (h) "Preliminary Inventory of the Water Resources of Idaho," John J. Peebles, Editor-in-Chief, Water Resources Research Inst., Univ. of Idaho, 598 p., 50 maps, Sept. 1968.

(6707)

BUBBLING PHENOMENA IN FLUIDIZED BEDS.

- (c) Dr. J. B. Romero, Assoc. Prof., Chem Engrg. Dept.
- (d) Experimental, basic; for M.S. thesis.
- (e) Determine characteristics of bubbles in fluidized beds.
- (f) Discontinued.
- (g) An X-ray unit has been calibrated for studies in fluidized beds.

(6709)

BUBBLING HEAT TRANSFER RESEARCH.

- (c) W. P. Barnes, Prof. Mech. Engrg.
- (d) Experimental; for M.S. thesis.
- (e) Comparison of transient boiling with steady-state boiling on SPERT-IV fuel rods.
- (f) Completed.
- (g) Transient boiling does not appear to be significantly different than steady-state boiling except in the heat fluxes at which nucleate boiling begins; transient boiling began at heat fluxes 10 times as great as steady-state nucleate boiling.
- (h) "Transient Boiling on SPERT-IV Capsule Driver Core Fuel Rods," S. A. Atkinson, unpublished M.S. thesis, Univ. of Idaho, June 1969.

(7317)

METHODOLOGY FOR EVALUATING POTENTIAL SURFACE-WATER RESERVOIR SITES IN IDAHO.

- (b) Idaho Water Resource Board.
- (c) John J. Peebles, Assoc. Prof., Civil Engrg. Dept.
- (d) Field investigation; operation.
- (e) To establish criteria for selecting optimum sites for surface-water reservoirs and to inventory existing and potential surface-water reservoir sites in Idaho.
- (g) Land-form studies are being made to develop criteria for reservoir site selection. A stream numbering system for Idaho has been established and a mileage index has been prepared for all of these streams. A tabulation and location map has been prepared for all existing reservoirs and lakes in the State with surface areas in excess of 40 acres and capacities in excess of 1,000 acre-feet, comprising a total of 230 reservoirs and lakes. Brief descriptions have been prepared of physical facilities for all reservoirs with capacities of 10,000 or more acre-feet, involving a total of 44 reservoirs.
- (h) "Methodology for Evaluating Potential Surface-Water Reservoir Sites in Idaho - Progress Report for Period of September 1, 1968, to September 30, 1969," John J. Peebles, Water Resources Research Inst., Univ. of Idaho, 59 p., Sept. 1969.

(7318)

DEVELOPMENT OF AN INFILTRMETER.

- (b) Agricultural Research Service, U.S. Dept. Agric.
- (c) V. E. Penton, Asst. Prof., Mech. Engr. Dept.
- (d) Experimental; design and development.
- (e) The objective is to design a variable drop size, variable intensity rain simulator and instrumentation to measure water movement into the soil in one portable system. This project replaces (6702) "A Study of Vectoplviometers."
- (g) System has been run in the field and changes are being made in increase drop size at high intensities.
- (h) Report in progress.

(7326)

ORIGIN AND PROPERTIES OF FIRE WHIRLS.

- (b) Office of Civil Defense.
- (c) Dr. H. J. Nielsen, Sr. Research Eng.
- (d) Theoretical and applied research.
- (e) Fire whirls are concentrated vortices and are closely related to the "dust devil" that can often be seen in hot arid areas. The purpose of the project was to investigate the mechanisms by which fire whirls are originated and their properties.
- (f) Completed.
- (g) Of the several mechanisms involved in the origin of fire whirls, the principal one is the lifting of the horizontal vortex lines in the natural wind. The vertical vorticity that results from this mechanism is then concentrated by local up-drafts in the fire.
- (h) "Origin and Properties of Fire Whirls," Hugo J. Nielsen, IITRI Report J6129 - for Office of Civil Defense, Washington, D.C. 20310 Contract No. N002-867-C-2760 Aug. 15, 1969.

(7327)

CROSSED-BEAM TECHNOLOGY FOR JET NOISE STUDIES.

- (b) NASA.
- (d) Experimental and applied research.
- (e) The program objective is to measure with an infra-red crossed-beam system point-area correlations of gas density-fluctuations in hot and cold high subsonic jets. The information obtained will be employed to estimate sound source intensity spectra, scaling laws and to compare results with available acoustic data and theory in similar jet flows.
- (g) A remote sensing crossed-beam system has been fabricated to determine mean and fluctuating carbon dioxide profiles in a cold subsonic jet using infra-red sources and detectors. This system is presently being employed to measure infra-red absorption spectrum for CO₂ gas.
- (h) "Application of Crossed-Beam Technology to Direct Measurement of Sound Sources in Turbulent Jets," L. N. Wilson Final Report on NASA Contract No. NAS8-21035 Feb. 1970.
"The Crossed Beam Correlation Technique," M. J. Fisher, and F. R. Krause, J. Fluid Mech. Vol. 28, p. 706, 1967.
"Optical Measurements with High Temporal and Spatial Resolution," M.J. Fisher and R.J. Damkevala, Final Report on NASA Contract No. NAS8-11258, Sept. 1967.

(7328)

FLOW STUDIES ON IMPLANTABLE ARTIFICIAL HEART VALVES.

- (c) Dr. J. M. Clinch, Res. Engr.
- (d) Experimental and applied research.
- (e) Tests were carried out to determine the steady state pressure drop and turbulence producing characteristics of a newly developed multi-tiered orifice type valve. The object was to develop experimental procedures for evaluating the flow performances of artificial heart valves. Comparisons were made between present conventional ball-cage heart valves and the multi-tiered orifice valve under steady flow conditions using tap water as the working fluid.
- (f) Completed.
- (g) The pressure drop tests indicated that the multi-tiered orifice valve had a flow resistance of about 2/3 of the ball-type valve. Turbulence data also showed that the turbulent intensity

produced by the orifice valve was about 20% less than the ball valve. However, comparative tests on the two valves showed that the orifice valve displaced 2.5 times more fluid than the ball valve during pressure release conditions.

- (h) IIT Research Institute, Internal R & D Report Project J1050, Jan. 1969.

ILLINOIS INSTITUTE OF TECHNOLOGY, Department of Mechanical and Aerospace Engineering, 3110 South State Street, Chicago, Illinois 60616. Andrew A. Fejer, Department Chairman.

(7329)

CAVITY OSCILLATIONS IN LIQUID PROPELLANT ROCKET MOTOR BAFFLE CAVITIES.

- (b) Air Force Office of Scientific Research.
- (c) T. P. Torda, IITRI Professor.
- (d) Experimental.
- (e) Investigation of secondary flows in odd-shaped (triangular, etc.) shallow cavities as excited by subsonic edgeflows and by shock waves traveling across the open mouth of the cavities.
- (h) "Analytical and Experimental Investigations of Oscillations in Rocket Motor Baffle Cavities," T. P. Torda and B. R. Patel - AFOSR-69-0181TR Jan. 1969. Available from Defense Documentation Center.
"Analytical and Experimental Investigations of Oscillations in Rocket Motor Baffle Cavities," Final Summary Report - AFOSR-68-1369 - May 1968. T. P. Torda and B. R. Patel. Available DDC.
"Investigations of Flow in Triangular Cavities," T. P. Torda and B. R. Patel, AIAA Jour. Vol. 7, 12, pp. 2365-2367, Dec. 1969.

(7330)

NAVAL HYDRODYNAMICS.

- (c) T. P. Torda, IITRI Professor.
- (d) Theoretical.
- (e) Analytical investigation (using numerical techniques to solve the boundary layer equations) of drag reduction and jet propulsion for deep-submergence research vehicles.
- (h) "Analysis of Jet Propulsion for Deep Submergence Vessels," submitted for presentation during the Symposium on Naval Hydrodynamics.

(7341)

V/STOL ORIENTED AERODYNAMIC STUDIES.

- (b) United States Air Force.
- (c) T. P. Torda, IITRI Professor.
- (e) Analytical investigation (using numerical techniques to solve the boundary layer equations) of boundary layer control by distributed surface suction. Analysis is aimed at prevention of flow separation by maintaining a thin, laminar boundary layer over two-dimensional thick airfoils with blunt trailing edges.

(7342)

JET MIXING STUDIES.

- (b) Defense Department (interdepartmental project "Themis").
- (c) Dr. Andrew A. Fejer, Professor.
- (d) Theoretical and experimental applied research.
- (e) Concerns the transfer of kinetic energy from a multiplicity of primary jets to a slower secondary flow. Analysis is based on empirical single jet mixing data. Experiments in multiple jet mixing tunnel are in progress.
- (g) Preliminary data indicate multiple jet performance derived from single jet data.

(h) IIT Themis Technical Note.

(7343)

ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF INCOMPRESSIBLE SWIRLING FLOW IN STATIONARY DUCTS.

(b) NASA Lewis Research Center, Cleveland, Ohio, and Aerospace Research Laboratories Dayton, Ohio.

(c) Dr. Z. Lavan.

(d) Analytical and experimental; basic study (masters).

(e) Turbulent swirling flows in stationary cylindrical ducts were investigated using Taylor's modified vorticity transport theory and von Karman's similarity hypothesis extended to consider a three-dimensional fluctuating flow field. The resulting similarity conditions are used to formulate expressions for the eddy viscosity. The results are compared with experimental studies performed in a 3-inch i.d. and 18-foot long lucite tube

(f) Suspended.

(h) "Analytical Investigations of Incompressible Turbulent Swirling Flow in Stationary Ducts," J. Appl. Mech., p. 151-158, June 1969.

"Measurements of the Decay of Swirl in Turbulent Flow," AIAA Jour., Vol. 7, No. 5, pp. 971-973, May 1969.

(7344)

STUDY OF ENERGY SPECTRAL DISTRIBUTION OF WATER FLOW IN PIPES USING DIFFERENT SENSING ELEMENTS.

(b) Air Force (Aerospace Research Laboratories, Dayton, Ohio).

(c) Dr. A. A. Fejer, H. M. Nagib, Dr. Z. Lavan, Swirling Flow Lab.

(d) Experimental basic research.

(e) Hot film, hot fiber, and thermistor probes are used to measure the RMS value of the fluctuating component of the axial velocity and its frequency spectral analysis in water flow through pipes at different Reynolds numbers. Emphasis is placed on the transition from laminar to turbulent flow regimes. The results obtained by the different sensing elements are compared and evaluated. The results at high Reynolds numbers (turbulent) are in agreement with those reported in the literature.

(g) The results indicate that sensing elements with limited frequency response (e.g. 10 C.p.s.) such as commercially available thermistors may be used to detect transition from laminar to turbulent flow regimes in water.

(h) "Experimental Investigation of the Hydrodynamic Stability of Flow in Rotating Pipes Using Thermistors," Proc. Symp. on Turbulent Measurements in Liquids, Rolla, Missouri, 1969.

(7345)

EFFECT OF ROTATION ON THE STABILITY OF AN AXIAL FLOW BETWEEN COAXIAL CYLINDERS.

(b) National Science Foundation.

(c) Dr. Z. Lavan, H. Nagib and A. A. Fejer, Swirling Flow Lab.

(d) Experimental; basic study (Master's and Doctoral).

(e) The stability of a fully developed axial flow in pipes and annuli with superposed solid body rotation is studied experimentally. In addition the effect of deviation from solid body rotation is also considered. The purpose of the study is to better understand the mechanism of a combined rotational and axial shear instability that causes transition of turbulence at low axial Reynolds numbers.

(g) Preliminary results indicate that the superposition of solid body rotation on an axial flow has a destabilizing effect.

(h) "On the Stability of Flow in Rotating Pipes," ARL Report No. 69-0176.

"Experimental Investigation of the Hydrodynamic Stability of Flow in Rotating Pipes Using Thermistors," Proc. Symp. on Turbulent Measurements in Liquids, Rolla, Missouri, 1969.

(7346)

MIXING OF LAMINAR HETEROGENEOUS JETS IN A CONFINED TUBE.

(b) NASA Lewis Research Center, Cleveland.

(c) Dr. Z. Lavan and H. Weinstein of Chemical Engineering Dept.

(d) Analytical and experimental; basic study (2 Ph.D. Theses).

(e) Numerical solutions of laminar mixing of confined jets were obtained by solving the boundary layer equations and the complete Navier-Stokes equations, respectively. Radius ratios and density ratios were varied over a large range. Velocity ratios ranging from zero to infinity were considered, and particular attention was directed to the occurrence of flow separation on the wall and recirculating cells near the axis. The results were compared with experimental data of others and with those obtained here. The present experimental investigation also establishes the region of laminar flow.

(g) For a given radius ratio there is a minimum velocity ratio below which no recirculation cells are formed within a finite range of Reynolds numbers. There are no cells at very low or very high Reynolds numbers.

(h) "Laminar Mixing of Heterogeneous Axisymmetric Coaxial Confined Jets," AIAA Jour., Vol. 7, No. 11, Nov. 1969.

(7347)

RECIRCULATING FLOWS IN TWO-DIMENSIONAL CAVITIES AND IN ROTATING CIRCULAR PIPES.

(b) NASA Lewis Research Center.

(c) Dr. Z. Lavan.

(d) Numerical calculations (Master's and Ph.D.).

(e) Numerical solutions of the Navier-Stokes equations were obtained for two geometries in which flow recirculation occurred. (1) A rectangular cavity in the lower wall of a two-dimensional channel, the upper wall of which is moving with a uniform velocity. (2) Flow in an infinite tube with the upstream section rotating and the downstream stationary and vice versa.

(f) Suspended.

(g) In the rectangular cavity problem one cell is present in the case of a shallow cavity. For deeper cavities the number of cells increases. In addition there is an infinite number of corner eddies of diminishing strength in the concave corners. In the rotating pipe problem criteria for incipient flow separation were obtained.

(h) "Separation and Flow Reversal in Swirling Flows in Circular Ducts," Physics of Fluids, Vol. 12, No. 9, Sept. 1969.

"Flow in a Two-Dimensional Channel With a Rectangular Cavity," J. Appl. Mech., Vol. 36, No. 4, Dec. 1969.

(7348)

ELECTROHYDRODYNAMIC BOUNDARY LAYER CONTROL.

(b) Defense Dept. (interdepartmental project "Themis").

(c) Dr. Robert W. Porter, Asst. Prof.

(d) Theoretical and experimental; basic and applied research.

(e) Concerns the use of electrostatic force for laminar boundary layer control on an airfoil. The force acts longitudinally on an electric charge sublayer introduced by a corona discharge. Theoretical analysis was based on the Karman-

Polhausen integral method. Experiment in low speed wind tunnel is in progress.

- (g) Theoretical analysis indicates control of laminar separation is speed limited. Scaling limits validity of theory to small scale sizes. Experiment was designed.
- (h) "Electrohydrodynamic Laminar Boundary Layer Control," IIT Themis Tech. Note 69-6, Sept. 1969.

ILLINOIS, STATE OF, Department of Public Works and Buildings, Division of Waterways, 201 West Monroe Street, Springfield, Illinois 62706. Mr. John C. Guillou, Chief Waterway Engineer.

- (1863)
- EROSION CONTROL, ILLINOIS SHORE OF LAKE MICHIGAN.
- (b) State of Illinois.
- (d) Field investigation; applied research.
- (e) To obtain and correlate basic data on the several forces and factors involved in erosion processes along the Illinois shore of Lake Michigan to the end that future efforts toward the prevention of erosion might be founded upon a more definite and factual basis with a consequent greater degree of assurance that the works will serve the intended purpose.
- (f) Discontinued.

- (5549)
- ILLINOIS RIVER.
- (b) State of Illinois.
- (d) Experimental; applied research.
- (e) A hydraulic model study is being conducted to determine the effects, on the upper Illinois River, of various flood relief measures proposed for the Illinois Waterway and Chicago Sanitary and Ship Canal.
- (g) Some preliminary results based on existing river system are completed.

- (5656)
- KINKAID CREEK DAM.
- (b) State of Illinois.
- (d) Experimental; applied research.
- (e) A hydraulic model study is being conducted to assist in the design of the spillway and stilling basin for a proposed reservoir to be constructed in Jackson County, Illinois.
- (g) Report of results submitted; concerns hydraulic performance of spillway and volume of natural plunge pool.

- (6094)
- NAPERVILLE DAM.
- (b) State of Illinois.
- (d) Experiment; applied research.
- (e) A hydraulic model study is being conducted to assist in the design of the outlet structure and stilling basin for a proposed reservoir to be constructed near Naperville, Illinois, in DuPage County.
- (g) Report of results submitted; concerns performance of spillway structure and stilling basin.

- (6095)
- MONTGOMERY LOCK.
- (b) State of Illinois.
- (d) Experimental; applied research.
- (e) A hydraulic model study is being conducted to determine the filling system for the proposed recreational navigation locks to be constructed in the Fox River at Montgomery, Illinois.
- (g) Preliminary report submitted on two-lock system

having a common filling wall.

ILLINOIS STATE WATER SURVEY, Box 232, Urbana, Illinois 61801. William C. Ackermann, Chief.

A list of publications is available upon request from Illinois State Water Survey at above address.

- (1865)
- HYDRAULIC DESIGN OF DROP-INLET SPILLWAY STRUCTURES FOR SMALL RESERVOIRS.
- (b) U.S. Dept. Agric., Agricultural Research Service, Soil Conservation Service; and Illinois Agric. Expt. Station.
- (c) Mr. H. W. Humphreys.
- (d) Experimental; generalized applied research for development and design.
- (e) To determine the most desirable proportions and shapes of drop-inlet spillway structures that have unique flow characteristics and to develop anti-vortex devices. To provide the necessary information on flow relations and discharge coefficients so that these structures may be economically designed. Experimental apparatus and tests conducted on the complete spillway. Information is being obtained on discharges, vortex effect on discharge, pressures, head loss coefficients, a flat plate anti-vortex device, and flow conditions.
- (f) Completed.
- (g) Model tests were performed on a drop-inlet spillway to determine whether or not a metal grating deck placed above the inlet can control vortices. The results of the tests show that gratings do not prevent or control strong vortices.
- (h) Report of Investigation 65 covers circulation effects, flat plate anti-vortex device effect, and vortex effect on model spillway performance.

- (2535)
- FILTERING THROUGH COARSE MATERIALS.
- (c) Mr. Ralph L. Evans, Peoria Lab., Illinois State Water Survey, Box 717, Peoria, Ill.
- (d) Experimental; basic research.
- (e) Small, coarse media (1/4- to 3/4-inch) filters are operated at rates comparable to those achieved in field practice. Purpose is to study the effects of coarse media on physical, chemical, and bacteriological properties of recharged water and to evaluate the function of coarse media in protecting aquifer materials.
- (f) Completed.
- (g) The results show that the suspended material passing through coarse media is dependent upon gravel size and depth, flow rate, and suspended solids in the applied water. Published as Report of Investigation 60.

- (4135)
- CORROSION PREVENTION BY CaCO_3 .
- (c) Dr. T. E. Larson or H. W. Humphreys.
- (d) Experimental.
- (e) To determine chemical requirements and velocity requirements to provide protective coating in water pipes.

- (7331)
- HYDRAULICS OF WATER TREATMENT PLANTS.
- (b) Chicago Water Filtration Plant.
- (c) Mr. H. W. Humphreys.
- (d) Experimental; applied research.
- (e) To improve the flow conditions in the various components of a water treatment plant. The first

project is a model study to improve the flow conditions in a settling basin. Model modifications will be made, the flow conditions observed, and velocity distributions measured to determine which modification is desirable to improve the flow conditions.

- (g) An experimental model of a settling basin is being designed. Development of a velocity meter capable of measuring small velocities is under way.

UNIVERSITY OF ILLINOIS, COLLEGE OF AGRICULTURE, Department of Agricultural Engineering, Urbana, Illinois 61801. Professor Benjamin A. Jones, Jr.

(008W)

RUNOFF FROM SMALL AGRICULTURAL AREAS IN ILLINOIS.

For summary, see Water Resources Research Catalog 3,0220, Volume 4.

- (h) "A Computer Program for Meteorologic Data Reduction," J. K. Mitchell and F. L. Anderson, Trans. Ill. State Acad. of Science, Vol. 62, No. 1, pp. 15-28, 1969.

(009W)

LABORATORY MODEL STUDIES OF CONSERVATION AND DRAINAGE STRUCTURES.

For summary, see Water Resources Research Catalog 3,0217, Volume 4.

- (h) "Factors Affecting Scour-Hole Development Upstream of a Rectangular Weir," A. O. Weiss, B. A. Jones, Jr., and R. N. Fenzl, Trans. ASAE. Vol. 11, No. 4, pp. 572-575, 1968.
"Better Erosion Control is Ultimate Aim of Studies with Artificial Rainfall," G. D. Bubenzner and J. K. Mitchell, Ill. Res., Vol. 11, No. 1, pp. 14-15, 1969.
"Irrigation Can Pay in Illinois," C. J. W. Drablos and F. J. Reiss, Ill. Res., Vol. 11, No. 4, pp. 3-5, 1969.
"Similitude Analysis of Tile Inflow," G. B. Johri, M.S. Thesis, Univ. of Ill. at Urbana Library, 1969.
"Effect of Drop Size and Impact Velocity on the Detachment of Soils Under Simulated Rainfall," G. D. Bubenzner, Ph.D. thesis, Univ. of Ill. at Urbana Library, 1970.

(010W)

HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS.

For summary, see Water Resources Research Catalog 6,0206, Volume 4.

- (h) "Laboratory Verification of Boundary Condition Assumptions for Solutions of the De Saint - Venant Equations," W. F. G. Brutsaert and R. N. Fenzl, Trans. ASAE, Vol. 11, No. 5, pp. 642-645, 1968.
"Morphological Analysis and Hydrologic Response of Small Agricultural Drainage Basins," R. A. Rastogi Ph.D., thesis, Univ. of Ill. at Urbana Library, 1968.
"Simulation and Hydrologic Response of a Drainage Net of a Small Agricultural Drainage Basin," R. A. Rastogi and B. A. Jones, Jr., Trans. ASAE, Vol. 12, No. 6, pp. 899-908, 1969.

(011W)

DEVELOPMENT OF DRAINAGE ASSESSMENT PROCEDURES BASED ON PHYSICAL FEATURES IN ILLINOIS.

For summary, see Water Resources Research Catalog 6,0207, Volume 4.

- (f) Terminated.
(h) "A Method for Distributing Drainage Assessments," R. L. Bengston, C. J. W. Drablos and B. A. Jones, Jr., Trans. ASAE, 12, No. 1, pp. 114-117, 1969.
"Development of Drainage Assessment Procedures Based on Physical Features in Illinois," B. A. Jones, Jr. and C. J. W. Drablos, Res. Rept. No. 19, Water Resources Center, University of Illinois, Urbana, 27 p., 1969.

(4987)

THE EFFECT OF GYPSUM AND DRAINAGE ON SOLONETZIC SOILS (SLICK-SPOTS) IN ILLINOIS.

- (b) In cooperation with Department of Agronomy.
(d) Experimental field investigation.
(e) To test the feasibility of replacing and removing excess sodium from solonchetsic soils under field conditions with (a) different methods and rates of applying gypsum (calcium sulphate), (b) different degrees of disturbing the subsoil, and (c) different spacings of tile drains.
Twenty plots were established in a random pattern to compare 3 positions for the application of gypsum and 3 spacings of tile drains with check plots. The tile effluent is measured by recording equipment to determine the rate and volume of flow. Also samples will be taken to determine the amount of sodium in the leachate.
(g) Corn yields have increased as a result of the application of gypsum and tile drainage.

UNIVERSITY OF ILLINOIS, Department of Chemistry and Chemical Engineering, Urbana, Illinois 61801. Professor Thomas J. Hanratty.

(6824)

STRUCTURE OF TURBULENCE CLOSE TO A WALL.

- (b) National Science Foundation.
(d) Experimental and theoretical; basic research; Ph.D. theses.
(e) Electrochemical techniques are used to study fluctuating wall shear stress, fluctuating mass transfer rates, fluctuating concentrations, and fluctuating velocities. The systems are pipes of 1-in. and 8-in. diameter.
(g) New information about the viscous sublayer, drag reduction and turbulent mass transfer.
(h) "A Study of Turbulence Close to a Wall," Physics of Fluids, Nov. 1967.

(6825)

FLOW OVER SOLID WAVES.

- (b) National Science Foundation.
(d) Experimental; basic research; Ph.D. theses.
(e) Pressures and shear stresses are being measured at the surface of solid waves over which a turbulent fluid is flowing.
(g) The work is giving new insight into the mechanism by which energy is transferred from a turbulent flow to a liquid surface.

(6826)

FLOW THROUGH PACKED BEDS.

- (b) National Science Foundation.
(d) Experimental; basic research; Ph.D. theses.
(e) Details of the flow around a sphere in a regular bed of spheres are being studied.
(g) At Reynolds numbers greater than 40 boundary layer theory is applicable. The definition of the singular points of the skin friction lines is of great use in characterizing the flow pattern.

- (h) "Use of Electrochemical Techniques to Study Mass Transfer Rates and Local Skin Friction to a Sphere in a Dumped Bed," A.I.Ch.E. Jour., 15, 199 (1969).

(6828)

INTERACTION BETWEEN A TURBULENT AIR AND FLOWING LIQUID.

- (b) National Science Foundation.
(d) Experimental, theoretical; basic Ph.D. theses.
(e) The structure of the waves at an interface is being studied. This includes roll waves that occur in gas-liquid flow, bores on thin liquid films, small amplitude systems of capillary-gravity waves.
(f) A model has been developed for finite amplitude roll waves.

UNIVERSITY OF ILLINOIS, Hydrosystems Laboratory,
Department of Civil Engineering, Urbana, Illinois
61801. Professor V. T. Chow.

(4543)

WATER RESOURCES SYSTEM ANALYSIS.

- (d) Theoretical applied research for doctoral thesis; H. Heidari directed by V. T. Chow.
(e) A supply and demand water resources system model is developed which consists of surface and sub-surface reservoirs and the demands for hydropower, irrigation and flood control. The model is optimized by differential dynamic programming for obtaining "near optimum" scales of development of the water resources system. The model so developed can be extended to simulating more complicated water resources systems.
(g) The model has been developed and tested for constant and variable inputs.

(4909)

A STUDY OF THE EFFECT OF BASIN STORAGE ON SURFACE RUNOFF HYDROGRAPHS.

- (d) Theoretical; basic research for doctoral thesis. (R. A. Rao directed by V. T. Chow.)
(e) To study the drainage basin taken as a lumped hydrologic system. Assuming a general nonlinear equation for the basin storage and combining it with the equation of continuity, a differential equation for the system is formulated. The equation is quasi-linearized by assuming that the coefficients are functions of the average inflow and outflow of the system.
(f) Completed.
(h) "Nonlinear Analysis of the Rainfall-Runoff Process," R. A. Rao, Ph.D. thesis, Univ. of Ill., 1968.

(5657)

HYDROLOGIC ANALYSIS BY ANALOG COMPUTERS.

- (d) Applied research.
(e) Direct and indirect analog computers are used for the analysis of hydrologic problems on surface and ground water. In the analysis of surface water problems, the EAL PACE computer of the Analog Computer Laboratory was employed to route floods through linear as well as nonlinear reservoirs. For the analysis of ground water, resistance networks were designed and analyzed for a number of ground water regions. The results will be recommended for use in the design and planning of water resources systems.
(f) Inactive.

(5660)

MICROSCOPIC DETERMINATION OF TRACTIVE FORCE DISTRIBUTION IN FREE-SURFACE WATER CONVEYANCES.

- (b) Office of Water Resources Research.
(c) Professor H. G. Wenzel.
(d) Experimental and basic research.
(e) The classical ultramicroscopic approach has been modified and developed for the determination of velocities within the viscous sublayer in open channel flow. The technique consists essentially of using a high-power microscope and dark-field illumination to observe the movement of small neutrally buoyant spheres suspended in the flow. High-speed photography permits the determination of the velocity of the spheres within the small optical depth of field.
(g) A preliminary study of laminar flow has been completed. Two-dimensional turbulent flow is being studied. Tractive force and turbulence data will be obtained.

(6187)

MECHANICS OF SURFACE RUNOFF.

- (b) National Science Foundation.
(d) Experimental and analytical; basic research.
(e) Basic mechanics of flow of water over artificial basins is studied by controlled experiments using a watershed experimentation system and by hydrodynamic analysis. The roughness of a conceptual river system is investigated, considering the drainage basin as a quasi-linear distributed dynamic system which is represented by a set of quasi-linear partial differential equations of continuity and momentum. The conceptual roughness was found to be sensitive to depth of flow and raindrop impact on the laboratory basin.
(f) Completed.
(h) "Mechanics of Surface Runoff," V. T. Chow, B. C. Yen and C. L. Chen, Final Prog. Rept., Dept. of Civil Engrg., Univ. of Ill., Urbana, Ill., Aug. 1969.
"On the Relationship Between Rainfall and Surface Runoff on Laboratory Watersheds," A. Ben-Zvi, Ph.D. thesis directed by V. T. Chow, Univ. of Ill., Urbana, Ill., Dec. 1969.

(6190)

BOUNDARY EFFECTS ON JET FLOW PATTERNS RELATED TO WATER QUALITY AND POLLUTION PROBLEMS.

- (b) Office of Water Resources Research.
(c) Professor W. H. C. Maxwell.
(d) Experimental and basic research.
(e) This experimental program will be divided into two phases: (1) Collection and analysis of further experimental data on velocity distributions downstream from a water jet introduced horizontally beneath the free surface of a deep reservoir. The diameter of the jet, submergence of the jet and velocity of the efflux from the jet will be varied systematically to determine their influence on the flow pattern. (2) Velocity traverses will be taken of the flow field downstream from a water jet introduced horizontally beneath the free surface of a shallow reservoir. The diameter and submergence of the jet, velocity of efflux and the vertical location and slope of the lower fixed boundary will be varied systematically.
(h) "A Method for Deaerating Water," W. H. C. Maxwell and E. R. Holley, Proc. Am. Soc. Civil Engrs., J. Hyd. Div., Vol. 95, pp. 577-580, 1969.
"Flux Development Region in Submerged Jets," W. H. C. Maxwell, Proc. Am. Soc. Civil Engrs., J. Eng. Mech. Div., in press.
"Boundary Effects on Jet Flow Patterns Related to

Water Quality and Pollution Problems," W. H. C. Maxwell and H. Pazwash, Res. Rept. No. 28, Water Resources Center, Univ. of Ill., Urbana, Ill., Jan. 1970.

(6191)

EFFECT OF RAINDROP IMPACT AND SURFACE ROUGHNESS ON SHEET FLOW.

- (b) Office of Water Resources Research.
- (c) Professor H. G. Wenzel.
- (d) Experimental and basic research.
- (e) The general objective of this research is to examine in detail both experimentally and theoretically the mechanics of sheet flow. This knowledge will be useful in improving the design of urban drainage facilities where this type of flow is common. More specifically the individual objectives are: (a) to investigate experimentally the effect of raindrop impact on sheet flow using carefully controlled laboratory rainfall, surface profile, and runoff measurements, (b) to study in detail the pressure fluctuations caused by raindrop impact using pressure transducers and to correlate this work with the results of the first objective, (c) to study the effect of roughness on sheet flow on a more thorough basis than has been previously attempted, and (d) to review the existing theoretical relationships describing sheet flow in the light of the experimental results so that, if necessary, modified equations can be developed which will reflect the true physical phenomenon.
- (h) "Effect of Rainfall on Sheet Flow," H. G. Wenzel, R. C. T. Wang and Y. N. Yoon, presented at 50th Annual Meeting, Am. Geophys. Union, April, 1969.

(7332)

EFFECTS OF OXYGEN DEMAND ON SURFACE REAERATION RATES.

- (b) Office of Water Resources Research.
- (c) Professor E. R. Holley.
- (d) Experimental; basic research.
- (e) For turbulent water flow with no oxygen demand, the coefficient of surface reaeration is proportional to the rate of turbulent energy dissipation. The presence of oxygen demand in the water can cause an increase in the reaeration coefficient. The amount of increase in the reaeration coefficient is being investigated for various types of oxygen demand, both analytically and experimentally, using a mixing vessel.

(7333)

HYDRAULIC RESISTANCE IN ALLUVIAL CHANNELS.

- (b) Office of Water Resources Research.
- (c) Professor B. C. Yen.
- (d) This is an analytical investigation directed at the determination of the hydraulic resistance for sediment-bearing flow in channels. Available experimental and field data are reanalyzed by a method involving dimensional analysis and the mechanics of fluid and sediment movement. The effects of the geometry of the channel, the properties of the sediment particles, and the characteristics of the flow are to be studied. The results will be presented in dimensionless general forms for engineering purposes such as river training, flood control, and canal design.
- (f) Completed.
- (h) "Hydraulic Resistance in Alluvial Channels," B. C. Yen and Y. C. Liou, Res. Rept. No. 22, Water Resources Center, Univ. of Ill., Urbana, Ill., July 1969.

(7334)

HYDRAULIC CHARACTERISTICS OF SIDE-CONTRACTION FLOW METER.

- (b) National Science Foundation.
- (c) Professor B. C. Yen.
- (d) Experimental; applied research.
- (e) A streamlined contraction along one side of a pipe can be used as a flow meter for clean or sediment-laden water. The advantages of such a meter are its low energy losses, ease of building, and inexpensiveness. By measuring the pressure and velocity distributions of the flow the hydraulic characteristics, with particular emphasis on energy losses, for the meter are investigated.

(7335)

METHODOLOGIES FOR FLOW PREDICTION IN URBAN STORM DRAINAGE SYSTEMS.

- (b) Office of Water Resources Research.
- (c) Professor B. C. Yen.
- (d) Theoretical and experimental; applied research.
- (e) This study involves theoretical and experimental investigations directed to determine flow of storm water in urban drainage systems. The urban drainage system is considered as an integrated system of components of urban surface, gutters, inlets, sewer branches, junctions, manholes, and other structures. Modern concepts in hydrology, fluid mechanics, and systems engineering are utilized to develop methods for quantitative prediction of storm runoff at various locations in an urban drainage system. Particular emphasis is given to the effects of urbanization, effects of inlets and junctions on the flow in the system, the interrelationship among the components and the possibility of optimization of the composition of the components.
- (h) "Risks in Hydrologic Design of Engineering Projects," B. C. Yen, Proc. ASCE, J. Hyd. Div., Vol. 96, No. HY4, April, 1970.

(7336)

STUDY OF THE HYDROLOGY FOR MODELS OF THE GREAT LAKES.

- (b) Office of Water Resources Research.
- (c) Professor D. D. Meredith.
- (d) Analytical; applied research.
- (e) Sophisticated quantitative analysis of precipitation, evaporation, and runoff for each of the Great Lakes and the Great Lakes as a system are being made in order to provide a better understanding of these relationships for future management of the water resources of the Great Lakes.
- (h) "Monthly Precipitation Charts for the Great Lakes Basin," D. M. A. Jones and G. E. Stout, presented at 12th Conf. on Great Lakes Research, 1969.

(7337)

HYDRODYNAMICS OF WATERSHED FLOW.

- (b) National Science Foundation.
- (d) Theoretical and experimental; applied research.
- (e) This research aims to apply the mathematical models developed in a previous NSF project (see No. 6187), with the experimental verification by the Watershed Experimentation System (WES), to practical problems such as flood control and urban drainage in the field of watershed hydraulics. The models are Illinois Hydrodynamic Watershed Models II and III respectively of one dimension and two dimension, consisting of a set of partial differential equations with appropriately prescribed initial and boundary conditions and with Darcy-Weisbach friction coefficient as measure of watershed roughness. They are normalized and solved on specified grid schemes by digital

- computer. The WES is an instrumental system which can produce an artificial storm on the laboratory drainage basin to test the mathematical models.
- (h) "Spatially Varied Flow Equations," V. T. Chow, Water Resources Res., Vol. 5, pp. 1124-1128, Oct. 1969.
- "A Laboratory Study of Surface Runoff Due to Moving Rainstorms," B. C. Yen and V. T. Chow, Water Resources Res., Vol. 5, pp. 989-1006, Oct. 1969.
- "Mechanics of Surface Runoff," V. T. Chow, B. C. Yen and C. L. Chen, Final Prog. Rept., Dept. of Civil Engrg., Univ. of Ill., Urbana, Ill., Aug. 1969.
- "On the Relationship Between Rainfall and Surface Runoff on Laboratory Watersheds," A. Ben-Zvi, Ph.D. thesis directed by V. T. Chow, Dec. 1969.

(7338)

ADVANCED METHODOLOGIES FOR WATER RESOURCES PLANNING.

- (b) Office of Water Resources Research.
- (d) Theoretical; applied research.
- (e) Advanced techniques of water resources planning which have not been generally introduced into practice are investigated. These techniques include mainly various methods of operations research such as stochastic analysis and dynamic programming. In this investigation, mathematical models are formulated for computer analysis and actual river basin data are tested in working procedures to be developed.
- (h) "Water Resources Systems Analysis: Part I. Annotated Bibliography on Stochastic Processes; Part II. Annotated Bibliography on Programming Techniques; Part III. Review of Stochastic Processes; Part IV. Review of Programming Techniques," V. T. Chow and D. D. Meredith, Civil Engrg. Studies, Hydr. Engrg. Series, Nos. 19 to 22, Dept. of Civil Engrg., Univ. of Ill., Urbana, Ill., July 1969.

(7339)

STOCHASTIC ANALYSIS OF HYDROLOGIC SYSTEMS.

- (b) Office of Water Resources Research.
- (d) Theoretical; applied research.
- (e) This research aims to develop a practical procedure by which the stochastic behavior of a hydrologic system can be adequately simulated. In the study a watershed is treated as the stochastic hydrologic system whose components are simulated by time series models. Emphasis is given to application of the procedure to the planning of rural and urban watersheds in Illinois.
- (h) "Stochastic Analysis of Hydrologic Systems," V. T. Chow, Res. Rept. No. 26, Water Resources Ctr., Univ. of Ill., Urbana, Ill., Dec. 1969.
- "Analysis of Stochastic Hydrologic Systems," V. T. Chow and S. J. Karellioris, presented at 51st Annual Mtg., Am. Geophys. Union, Wash., D. C., April 1970.

(7340)

EVALUATION OF FLOOD GENERATION CHARACTERISTICS.

- (d) Theoretical; applied research.
- (e) Flood data at ten stream gaging stations on rivers in Illinois are analyzed for their characteristics of flood generation on the basis of the theory of nonparametric probability distributions. Once the probability model for flood occurrences is formulated, flood sequences are generated by the Monte Carlo method and then compared with historical flood sequences.

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UNIVERSITY OF ILLINOIS, Fluid Mechanics and Hydraulics Laboratory, Department of Theoretical and Applied Mechanics, Urbana, Illinois 61801. Professor T. J. Dolan, Department Head. Professor J. M. Robertson, Area Coordinator for Fluids.

(2536)

STUDY OF HOMOLOGOUS TURBULENCE.

- (c) Professor J. M. Robertson, Talbot Laboratory.
- (d) Basic research.
- (e) The nature of turbulence (its production and dissipation) is being studied in the simplest possible shear flow-plane Couette flow where the shear is constant and the turbulence homogeneous but not isotropic. Mean-flow studies essentially complete.
- (f) Suspended.
- (h) Paper in progress.

(3427)

STRUCTURE OF TURBULENCE NEAR ROUGH SURFACES.

- (b) Naval Ship Systems Comm., General Hydromechanics Research Program.
- (c) Professor J. M. Robertson, Talbot Laboratory.
- (d) Basic research; experimental.
- (e) Information on mean-flow and turbulence structure near roughnesses being studied in an 8-inch "natural roughness" pipe and in 3-inch sand-roughened pipe.
- (h) "Turbulent Flow in Rough Pipes," J. M. Robertson, J. D. Martin and T. N. Burkhardt, I & EC Fund., Vol. 7, 1968, pp. 253-265.

(4142)

TURBULENT BOUNDARY-LAYER FLOW TOWARDS A NORMAL STEP.

- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic research.
- (e) An analytical and experimental study is being made of upstream separation, i.e., the real fluid behavior (separation, mixing, reattachment) in front of a normal step projecting inward from a plate along which fluid is flowing with a turbulent boundary layer. Air is fluid medium being used.
- (f) Suspended.
- (g) First phase of study completed; in one case rather good agreement was found between theoretical solution and experimental observation of separation streamline.
- (h) "Turbulent Boundary Layer and Separation Flow Ahead of a Step," J. M. Robertson and D. B. Taubee, Developments in Mechanics, Vol. 5, 1969, pp. 171-183; second paper in progress.

(4143)

HEMODYNAMICS SIMILITUDE STUDY OF AN ARTERIAL DISTRIBUTION SYSTEM.

- (b) Public Health Service, Natl. Insts. of Health.
- (c) Prof. M. E. Clark, Talbot Laboratory.
- (d) Basic research; experimental.
- (e) The flow of blood in the Circle of Willis--the arterial distribution system for the brain--is to be studied utilizing large-sized models. Present goal is to fabricate a model which will simulate in as many ways as possible the prototype and its flow.
- (g) Solutions to cerebral circulation problems are being sought via simulation techniques using rigid vessel-steady flow and flexible vessel-pulsatile flow models. The current aim is to develop a better engineering understanding of pulsatile flow in flexible vessel networks both analytically (via impedance methods) and experimentally (via latex tube networks pulsed sinusoidally). Networks that both branch and loop are being studied

- to assess the importance of these aspects to physical and physiological problems.
- (h) "A Comparative Examination of Cerebral Circulation Models," M. E. Clark, W. A. Himwich and J. D. Martin, *J. Neurosurgery*, 1968, Vol. 29, No. 5, 484-494.
- "Precursor Cerebral Circulation Models," M. L. Roller and M. E. Clark, *J. Biomechanics*, 1969, Vol. 2, 241-250.
- (5777)
THREE-DIMENSIONAL EFFECTS IN TURBOMACHINERY.
- (b) Caterpillar Tractor Company.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic research, experimental and analytical, for Ph.D. thesis.
- (e) Radial inward flow system studied in terms of base flow, boundary layer and secondary flow occurrences.
- (f) Suspended.
- (g) Non-rotating test rig with some features of rotating system simulated by adjustment in blade contours to give same absolute flow paths on assumption of no separation. An unexpected flow separation was found on blade suction surface. This was not predictable by ordinary two-dimensional boundary-layer analysis and was found not to be due to secondary flows, although such were present. Methods of secondary flow prediction are extended to predict their development from growing boundary on channel side walls.
- (h) "Blade Channel Flow in a Simulated Radial-Flow Turbomachine," R. C. Hansen, Ph.D. thesis, TAM Dept., Univ. of Ill., June 1967, TAM Rept. 297, July 1967.
- (5778)
BODY DRAG AT LOW REYNOLDS NUMBERS.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic analytical and experimental research.
- (e) Except for flat plate, analytical drag relations are available only in the creeping motion and boundary layer regimes. Experimental data is available only for a few other bodies in the intermediate (Navier-Stokes) range. Objective of study is to help fill this gap.
- (g) Current effort is aimed at extending experimental information on drag of simple bodies (flat plate and ellipsoids).
- (5779)
UNIQUE ASYMPTOTIC EXPANSIONS IN THE THEORY OF HYDRO-DYNAMIC STABILITY.
- (b) National Science Foundation.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Theoretical; basic research.
- (e) Asymptotic approximations of certain functions which occur in hydrodynamic stability are being studied with reference to their uniqueness; error bounds for such approximations are being studied also.
- (g) Have obtained explicit representations for functions which satisfy the differential equations pertinent to the stability theory and which have asymptotic approximation identically equal to zero.
- (6139)
LONGITUDINAL CURVATURE EFFECTS ON TURBULENT BOUNDARY LAYER.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic; experimental and analytical.
- (e) Boundary curvature in flow direction causing pressure difference between wall and edge of layer is known to affect laminar boundary layer and there is some suggestion of its effect on turbulent layers. Flow of a turbulent layer of several thicknesses along a circular surface is being studied to evaluate the occurrences.
- (6140)
TURBULENT FLOW IN ECCENTRIC ANNULI.
- (b) ASCE Research Study for Fed. Water Pollution Control Administration.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Experimental and analytical.
- (e) Interest is in effect of "inserted pipe on flow capacity of a sewer." Experiments have involved concentric and eccentrically located one-inch and two-inch (OD) pipes in six-inch line. Analysis involves more details and effects of different surface roughnesses.
- (f) Suspended.
- (g) Effect of eccentricity is marked. At full eccentricity friction factor may be reduced to 0.65 of concentric value depending on insert size.
- (h) "Turbulent Friction in Eccentric Annular Conduits," J. M. Robertson, TAM Rept. 310, 1968.
- "Analytical Studies of Turbulent Friction in Annular Conduits," A. R. Nelson and J. M. Robertson, TAM Rept. 321, 1968.
- (6141)
VAPOR FORMATION DURING WATER HAMMER.
- (c) Prof. C. E. Bowman, Talbot Laboratory.
- (d) Basic analytical and experimental research.
- (e) Purpose was to study bubble formation during pressure transients in water filled pipeline. Appearance of voids and their effect on wave propagation after valve closure is studied.
- (g) The pressure-time history of water hammer accompanied by bubble formation was found identical with usual prediction for the first, second and third passages of pressure wave. Celerity of fourth pressure wave is found to depend on quality of the water bubble mixture. Kinetic energy of fluid during the low pressure portion of the occurrences was not all converted into pressure energy as during normal water hammer, but some of it remains as kinetic.
- (h) "Water Hammer Accompanied by the Formation of Air-Vapor Bubbles," S. R. Schoening, M. S. thesis, TAM, Jan. 1970.
- (6143)
ABNORMALITY DETECTION IN THE CEREBRAL CIRCULATION VIA FLUID IMPEDANCE CHANGES.
- (b) St. Paul-Ramsey Hospital, St. Paul, Minnesota.
- (c) Prof. M. E. Clark, Talbot Laboratory.
- (d) Experimental and theoretical; applied research.
- (e) Diagnostic investigations of the cerebral circulation would be enhanced if not only the presence of system abnormalities but their severity and clinical significance could be evaluated. Such abnormalities give rise to pressure and flow reflections and since fluid impedance relates pulsatile pressure to flow, changes in impedance can be used to detect and evaluate their presence. Experimental and computer models of systems containing stenoses, aneurysms, and other discontinuities have been studied and recognition patterns have been developed from impedance results.
- (h) "Abnormality Detection in Simulated Artificial Systems," M. E. Clark and G. F. Ayala, *J. Engr. Mech. Div., ASCE*, Oct. 1969, 1189-1215.
- "Impedance Analyses of Model and Prototype Arterial Systems for Abnormality Effects," 21st ACEMB, Vol. 10, 1968, pp. 23.4.
- (7351)
TURBULENT BOUNDARY LAYER FLOW ON FLAT PLATE.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic research; experimental and review of

literature.

- (e) Refurbishing of theory for layer, assessment of transition occurrences in terms of leading edge, stream turbulence level and roughness or trips; a second phase concerns effect of high stream turbulence level on a turbulent layer.
- (f) Experiments under way on second phase.
- (h) "Growth of the Turbulent Flat-Plate Boundary Layer," J. M. Robertson, ASEE Mechanics Monograph M-1, 1969, pp. 14-21; second paper in progress.

(7352)

FORCES ON BODIES IN NON-NEWTONIAN FLUIDS.

- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic research; also Ph.D. thesis.
- (e) Nature of body-force relations (particularly drag) for bodies in relative motion with fluids such as Bingham plastics. Experiments have been carried out with clay-water mixtures (and on their viscometry) and are planned for other fluids. Analytical work on extending theoretical formulations.
- (h) "Fluid-Dynamic Consideration of Bottom Materials," H. Pazwash and J. M. Robertson, ASCE Proc. 1969 Ocean Engrg. Conf.; other papers in progress.

(7353)

NOISE PRODUCTION IN FLUID-POWER SYSTEMS.

- (b) Sundstrand Aviation.
- (c) Prof. J. M. Robertson, Talbot Laboratory.
- (d) Basic research, analytical in nature with experiments planned.
- (e) The manner of noise generation by pressure transients in the cylinders of positive-displacement pumps is being studied via analysis and analog experiments (water table) of wave motions.
- (h) "Noise of Fluid-Power Systems - A Literature Review," C. F. Holt and J. M. Robertson, TAM Rept. 324, 1969.

(7354)

CALCULATIONS FOR OSCILLATORY FLOW IN A RIGID PIPE.

- (b) Public Health Service, NIH.
- (c) Prof. M. E. Clark, Talbot Laboratory.
- (d) Basic research - numerical.
- (e) Numerical finite difference solutions to oscillatory flow in plane two-dimensional and axisymmetric conduits are being developed to assess the suitability of both explicit and implicit procedures, establish the computational stability criteria, and determine the time required to reach steady state.

(7355)

NUMERICAL ANALYSIS OF LAMINAR OSCILLATORY NAVIER-STOKES FLOWS PAST TWO-DIMENSIONAL AND AXISYMMETRIC HUMPS.

- (b) InterScience Research Institute, Champaign, Ill.
- (c) Prof. M. E. Clark, Talbot Laboratory.
- (d) Theoretical and basic research for Ph.D. thesis.
- (e) Fluid dynamic occurrences in simple conduits for flows through various types of geometric barriers are being theoretically and experimentally correlated for comparison with hemodynamic occurrences in similar physiological situations. This thesis work is attempting to develop the analysis by finite difference solution of the appropriate Navier-Stokes equations.
- (g) Some preliminary results for square humps in the plane case have been achieved at low and moderate values of the oscillatory flow parameter $R\sqrt{f}/v$ where R is the plate spacing, f the frequency of oscillation, and v the kinematic viscosity of the fluid.

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UNIVERSITY OF ILLINOIS AT CHICAGO CIRCLE, Department of Energy Engineering, College of Engineering, Box 4348, Chicago, Illinois 60680. J. P. Hartnett, Department Head.

(7349)

EFFECTS OF IRREGULAR GEOMETRIES AND OSCILLATORY MOTION UPON BLOOD OXYGENATION.

- (b) Univ. of Ill. Chicago Circle Research Board.
- (c) Dr. Joseph C. F. Chow, Associate Professor.
- (e) The specific aim of the project is to obtain the quantitative analysis of oxygen uptake and carbon dioxide elimination in an oxygenator using various geometries based on the established theory on laminar flows. Initially, we shall consider the flow problem inside an axisymmetric wavy channel to find out the effects of the width and shape of the channel upon the oxygen transport. It will be followed with axisymmetric tubes with and without oscillatory motion.

(7350)

A STATISTICAL THEORY OF TURBULENT, CHEMICALLY REACTING FLOW.

- (b) National Aeronautics and Space Administration.
- (c) Dr. Paul M. Chung, Professor.
- (e) The conventional phenomenological theories of turbulent shear flows are inherently incapable of describing the chemical reaction in a turbulent flow field. The state of the art, on the other hand, of the classical, statistical turbulence theories is such that it cannot be employed to analyze the complicated chemically reacting flow problem. We have developed a new, statistical model of a turbulence field, which describes the chemical reactions in turbulent shear flow fields in a tractable manner. This theory has been successfully employed to analyze various flows associated with combustion and plasmas. This theory is able to explain the various fundamental phenomena which have been previously observed experimentally, but have not been explained theoretically.

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INDIANA, STATE OF, Surface Water Section, Division of Water, Department of Natural Resources, State Office Building, Indianapolis, Indiana 46204. Dr. Ramanand Prasad, Section Head.

(7356)

FREQUENCY ANALYSIS OF HYDROLOGIC INFORMATION.

- (d) Applied research.
- (e) A comparative study of various methods of hydrologic frequency analysis to find the best method for the mid-western United States.
- (f) Completed.
- (g) Log-Pearson method was found to be the best for the Midwest. A probability paper for this method is available for quick graphical analysis.
- (h) Preliminary report available.

(7357)

NUMERICAL METHOD OF COMPUTING FLOW PROFILES.

- (d) Applied research.
- (e) Computation of gradually varied steady flow profiles in channels and natural rivers using a numerical method.
- (g) A computer program is available.
- (h) "Numerical Method of Computing Flow Profiles,"

- (7358)
FLOOD FREQUENCY OF INDIANA STREAMS.
(d) Applied research.
(e) Magnitude and frequency of floods in Indiana may be estimated.
(f) Completed.
(g) A nomograph has been developed to compute the floods.

- (7359)
A NUMERICAL SOLUTION OF FLOOD ROUTING PROBLEMS.
(d) Applied research.
(e) A numerical method for flood routing using continuity and storage equations has been developed.
(f) Completed.
(g) Report available.

- (7360)
(d) Applied research.
(e) A study of nonlinearities in the response of the basin.
(f) Discontinued.
(g) Nonlinearities in the system response were successfully correlated with the basin main channel and rainfall characteristics.
(h) "Nonlinear Hydrologic System Response Model," Ramanand Prasad, J. Hyd. Div., ASCE, Vol. 93, No. HY4, pp. 201-221, July 1967.

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INDIANA UNIVERSITY, Department of Geology, Bloomington, Indiana 47401. Robert H. Shaver, Acting Department Chairman.

- (7576)
RADIAL FLOW PROBLEMS.
(h) "Some Approximate Solutions for Radial Flow Problems," Y. M. Sternberg, J. Hydrology, No. 2, Vol. 7, pp. 158-166, 1969.
"Flow to Wells in Presence of Radial Discontinuities," Ground Water, No. 6, Vol. 7, pp. 17-20.

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INGERSOLL-RAND RESEARCH, INC., Box 301, Princeton, New Jersey 08540. Dr. W. A. McGahan, Director of Research.

- (7361)
PERFORMANCE OF UNSTEADY EJECTOR.
(c) Kenneth Kaufman, Fluid Mechanics Section.
(d) Experimental; applied research.
(e) Investigation of ejector systems with intent of improving performance and decreasing required length by use of an unsteady primary flow. Theory implied large performance increases. Several different primary flow systems were investigated experimentally and the associated ejector performance determined. Low pressure air was the fluid used.
(f) Suspended.
(g) Determined that unsteady ejector systems require mixing tube lengths significantly less than those of steady ejectors and have a slightly lower performance than the optimum steady ejectors. Optimization of the unsteady ejector system, particularly the nozzle, should increase its performance with no change in required length.

(h) Report in preparation.

- (7362)
ALTERNATING FLOW POWER TRANSMISSION IN LONG LINES.
(c) E. Krasnoff, Fluid Mechanics Section.
(d) Experimental and theoretical; applied research.
(e) Study of the characteristics of pressure waves in long hydraulic lines including the effects of fluid viscosity, tube wall elasticity and damping, undissolved air content, and line termination. Includes investigation of pressure wave filter concepts.
(g) It has been shown that efficient power transmission via pressure waves in long hydraulic lines can be achieved when the wall damping is of the order of or less than the critical value. When the termination is a mass-spring-dashpot system it is possible to tune the system so that power is transmitted without the appearance of standing waves in the line.
(h) Internal reports only.

- (7363)
STUDY OF JET-FLAP CASCADES.
(c) E. Krasnoff and T. J. Landsberg.
(d) Experimental and theoretical; applied research.
(e) Study of the performance of jet flap cascades in rectilinear configuration. Both conventional jet-flap airfoils (normal blowing) and airfoils with jets blowing over rounded trailing edges were evaluated.
(f) Completed.
(g) Test results on normal blowing jet-flap cascades are in good agreement with a lattice effect theory. Stream turning angle is specified as a function of jet momentum coefficient and cascade solidity. The tangential blowing airfoil configuration typically led to a doubling of cascade performance.
(h) "Stream Deflection Produced by a Cascade of Jet-Flap Airfoils," E. Krasnoff, Trans. ASME, J. Basic Engrg., 91, D, 3, 553-5.
"An Experimental Study of Rectilinear Jet-Flap Cascades," T. J. Landsberg and E. Krasnoff, submitted to ASME.

- (7364)
ANALYSIS AND EXPERIMENTS ON THE HYDRAULICS OF VORTEX PUMPS.
(c) G. P. Schivley and J. L. Dussourd.
(d) Analytical and experimental; applied research.
(e) An investigation by analytical and experimental means of the quantitative flow pattern in a pump that has a recessed impeller and a large free space in front, in which a forced vortex is formed.
(f) Completed.
(g) It was determined that a secondary toroidal vortex exists superposed upon the main vortex coaxial with the impeller. Calculation is made of the complex velocity field and this is corroborated with detailed experimental surveys. The overall pump performance can be determined therefrom and this is checked with measured performance on several pumps of various geometries. Data were also prepared defining the affinity laws for this type of pump.
(h) "An Analytical and Experimental Study of a Vortex Pump," G. P. Schivley and J. L. Dussourd, presented at ASME Fluids Engrg. Conf., May 27, 1970.

- (7365)
A UNIFIED PROCEDURE FOR THE CALCULATION OF OFF-DESIGN PERFORMANCE OF RADIAL TURBOMACHINERY.
(c) J. L. Dussourd, Assistant Director.
(d) Analytical and experimental; applied research,

- useful for design.
- (e) Permits the calculation of the pressure-flow and efficiencies characteristics for centrifugal pumps and compressors under subsonic conditions.
 - (f) Completed.
 - (g) The method was computerized and checked against five impellers and three diffusers. Acceptable agreement is found in the calculation of the shape of the characteristics and the location of the surge and choke points.
 - (h) "A Unified Procedure for the Calculation of Off-Design Performance of Radial Turbomachinery," R. C. Davis and J. L. Dussourd, presented at Gas Turbine Power Conf. & Products Show, Brussels, Belgium, May 24-27, 1970. A.S.M.E. Paper No. 70-GT-64. To be published in A.S.M.E. J. Engrg. for Power.

INTERNATIONAL BUSINESS MACHINES CORPORATION, Research Laboratory, Large Scale Scientific Computation Department, Hydrodynamics Group, Monterey and Cottle Roads, San Jose, California 95114. Andrew H. Eschenfelder, Director.

- (7366)
DESIGN, DEVELOPMENT AND APPLICATION OF NUMERICAL METHODS IN THE SOLUTION OF NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS BY FINITE DIFFERENCE METHODS.
- (c) Jacob E. Fromm - K07/024.
 - (d) Theoretical; basic research.
 - (e) Finite difference algorithms are designed to replace a set of coupled nonlinear partial differential equations thereby permitting step by step integration through systems of algebraic equations. Initial-boundary value problems are addressed through conditions established on a finite net of points. The objective is to establish accurate and stable difference approximations, program them for efficient computation, and to test their validity in applications where no other means of solution exist.
 - (g) Fourth order nonlinear algorithms have been developed which extend the range of parameters that may be treated in applications; numerical solutions of buoyant air circulation in rooms.
 - (h) "Practical Investigation of Convective Difference Approximations of Reduced Dispersion," J. E. Fromm, IBM Res. Rept. RJ531, 1968.
"Numerical Solution of Two-Dimensional Stall in Fluid Diffusers," J. E. Fromm, IBM Res. Rept. RJ541, 1968.
"Lectures on Large Scale Finite Difference Computation of Incompressible Fluid Flows," J. E. Fromm, IBM Res. Rept. RJ617, 1969.

INTERNATIONAL BUSINESS MACHINES CORPORATION, Thomas J. Watson Research Center, P. O. Box 218, Yorktown Heights, New York 10598. Dr. A. G. Anderson, Director.

- (7367)
HYDROLOGY PROGRAM.
- (b) Geography Program, Office of Naval Research.
 - (c) Dr. J. S. Smart.
 - (d) Basic and applied theoretical research.
 - (e) Stochastic processes in hydrology and geomorphology.
 - (h) "A Comment on Horton's Law of Stream Numbers," J. S. Smart, Water Resources Res. 3, 773-776, 1967.
"The Relation Between Mainstream Length and Area in Drainage Basins," J. S. Smart and A. J. Surkan,

- Water Resources Res. 3, 963-974, 1967.
"Digital Simulation of Channel Networks," J. S. Smart, A. J. Surkan, and J. P. Considine, Intl. Assoc. Sci. Hydrol. Publ. No. 75: Symp. River Morphology, 87-98, 1967.
"Factor Analysis in Hydrology - An Agnostic View," J. R. Wallis, Water Resources Res. 4, 521-528, 1968.
"Noah, Joseph, and Operational Hydrology," B. B. Mandelbrot and J. R. Wallis, Water Resources Res. 4, 909-918, 1968.
"Statistical Properties of Stream Lengths," J. S. Smart, Water Resources Res. 4, 1001-1014, 1968.
"Mean Stream Numbers and Branching Ratios for Topologically Random Channel Networks," Intl. Assoc. Sci. Hydrol. Bull. 13, 61-64, 1968.
"Self-Similar Synthetic Hydrology," J. R. Wallis and B. B. Mandelbrot, Intl. Assoc. Sci. Hydrol. Publ. No. 81: The Use of Analog and Digital Computers in Hydrology, Vol. II, 738-755, 1968.
"Synthetic Hydrographs: Effect of Network Geometry," A. J. Surkan, Water Resources Res. 5, 112-128, 1969.
"Computer Experiments with Fractional Gaussian Noises. Part 1: Averages and Variances. Part 2: Rescaled Ranges and Spectra. Part 3: Mathematical Appendix," B. B. Mandelbrot and J. R. Wallis, Water Resources Res. 5, 228-267, 1969.
"Some Long-Run Properties of Geophysical Records," B. B. Mandelbrot and J. R. Wallis, Water Resources Res. 5, 321-340, 1969.
"Topological Properties of Channel Networks," J. S. Smart, Geol. Soc. Amer. Bull. 80, 1757-1774, 1969.
"Robustness of the Rescaled Range R/S in the Measurement of Noncyclic Long-Run Statistical Dependence," B. B. Mandelbrot and J. R. Wallis, Water Resources Res. 5, 967-988, 1969.
"Distribution of Interior Link Lengths in Natural Channel Networks," J. S. Smart, Water Resources Res. 5, 1337-1342, 1969.
"Constrained Random-Walk Meander Generation," A. J. Surkan and J. Van Kan, Water Resources Res. 5, 1343-1352, 1969.
"Comparison of Smart and Scheidegger Stream Length Models," J. S. Smart, Water Resources Res. 5, 1383-1387, 1969.

IOWA INSTITUTE OF HYDRAULIC RESEARCH, University of Iowa, Iowa City, Iowa 52240. Dr. John F. Kennedy, Director.

- (66)
HYDROLOGIC STUDIES, RALSTON CREEK WATERSHED.
- (b) Agricultural Research Service and U. S. Geological Survey.
 - (c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, Univ. of Iowa.
 - (d) Field investigation; applied research, and M.S. theses.
 - (e) Study continuously in progress since 1924 on the three square-mile north branch of Ralston Creek. This involves discharge measurement by the U.S.G.S. and rainfall measurement at 5 automatic recording stations. It is collected by the Agricultural Research Service and published by the Weather Bureau. An area of similar size on the south branch of Ralston Creek came under observation in 1967. A record of the urbanization of the area through aerial photos and numerous pictures taken at the same point year after year is being accumulated. Records on rainfall, runoff, groundwater levels, sediment transportation, and land use are

- combined in an annual report.
- (g) Yearly records available for examination at Iowa Inst. of Hydraulic Research.
 - (h) Reports prepared annually since 1924 available in files at the Iowa Inst. of Hydraulic Research. Summary of 33-year record published as Bull. 16 of the Iowa Highway Research Board in 1961; available upon request from Iowa Highway Commission, Ames, Iowa.
- (67)
COOPERATIVE SURFACE-WATER INVESTIGATIONS IN IOWA.
- (a) U.S. Geological Survey, Agriculture Research Service, U.S. Weather Bureau, IIHR, Graduate College.
 - (c) District Chief, Water Resources Div., U.S. Geol. Surv., Iowa City, Iowa.
 - (d) Field investigation; collection of basic stream-flow data.
 - (e) Stream-flow and sediment measuring stations maintained throughout the State of Iowa cooperatively on a continuous basis. Records collected by standard methods of U.S.G.S.
 - (g) Records of stream-flow and sediment discharge computed yearly.
 - (h) Records contained in open-file reports published annually, and in Water-Supply Papers published at 5-year intervals, are available from U.S. Geological Survey.
- (73)
MEASUREMENT OF TURBULENCE IN FLOWING WATER.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Dr. John R. Glover.
 - (d) Experimental; design.
 - (e) A bi-directional counter, to operate with Model Old Gold Hot Wire Anemometer is being developed. The bi-directional feature will permit direct long-term integrations of products associated with turbulence measurements.
 - (g) Results obtained from hot wires coated with urethane indicate that coated wires may be used in liquids for a period of approximately one hour before experiencing the usually encountered drift problems. The frequency response of the coated wires has been found to be flat to at least 1 kHz. A vortex shedding technique is used for this evaluation.
- (79)
CAVITATION.
- (b) Office of Naval Research, Dept. of the Navy.
 - (c) Dr. Hunter Rouse.
 - (d) Experimental and theoretical; basic research and graduate theses.
 - (e) Basic information is sought on cavitation for systematically varied boundary conditions. Studies of cavitation in abrupt conduit expansions are now being pursued.
 - (f) Completed.
 - (h) "Fluctuations of Pressure in Conduit Expansions," Hunter Rouse and Vladimir Jezdinsky, J. Hydr. Div., ASCE Vol. 92, No. HY3, Proc. Paper 4815, May 1966, pp. 1-12.
"Jet Diffusion and Cavitation," (Freeman Memorial Lecture), Hunter Rouse, J. Boston Soc. Civ. Engrg., Vol. 53 No. 3, July 1966, pp. 255-271.
- (1875)
CHARACTERISTICS OF STABLE EDDIES.
- (c) Dr. Enzo O. Macagno.
 - (d) Experimental and analytical; basic research.
 - (e) Eddies in viscous internal flows are studied both experimentally and theoretically in conduit expansions.
- (g) Calculations have been completed for eddies in two-dimensional flow expansions which are originated by a sudden jump in the discharge. Paper to be published.
 - (h) "Growth of Eddies in a Flow Expansion," E. O. Macagno and T. K. Hung, Seventh Symp. Naval Hydrodynamics, Rome, Aug. 1968.
- (2091)
RESEARCH ON SHIP THEORY.
- (b) Office of Naval Research and Naval Ship Res. and Dev. Ctr.
 - (c) Dr. Louis Landweber.
 - (d) Experimental and theoretical; basic research.
 - (e) To determine the laws governing the forces, moments, and motions of ships. Work is under way on the following problems: (1) development of procedure for computing potential flow about ship forms; (2) higher-order gravity wave theory for an immersed prolate spheroid; (3) effect of tank size on ship-model resistance; (4) resolution of viscous and wave drag by means of wake and surface-profile measurements; (5) vibration of ships; (6) effect of a dilute solution of guar-gum on resistance; (7) thick boundary layers on bodies of revolution.
 - (h) "Irrotational Flow about Ship Forms," L. Landweber and M. Macagno, IIHR Rept. 123, Dec. 1969.
"Potential Flow about a Prolate Spheroid in Axial Horizontal Motion Beneath a Free Surface," C. Farell, Ph.D. dissertation, Univ. of Iowa, Aug. 1968.
"On the Linearized Theory of the Wave Resistance of a Submerged Spheroid," C. Farell, XIIth Congr. Appl. Mech., Stanford Univ., Aug. 1968.
"Expansion of a Basic Solution of the Laplace Equation in Spheroidal Harmonics with an Application to the Solution of a Potential Flow Problem," C. Farell, Sixth U.S. Natl. Congr. Appl. Mech. A Free-Streamline Model of a Two-Dimensional Wake," A. C. Lin, Ph.D. Dissertation, Univ. of Iowa, June 1970.
"Effect of a Rotational Wake on the Wave-Making Resistance of an Ogive," J. C. Tatinclaux, Ph.D. Dissertation, Univ. of Iowa, June 1969.
"On the Determination of the Viscous Drag of a Ship Model," T. S. Tzou, Ph.D. Dissertation, Univ. of Iowa, June 1969.
"Natural Frequencies of a Body of Revolution Vibrating Transversely in a Fluid," L. Landweber, IIHR Rept. 111, Aug. 1968.
"Effect of High-Polymer Additives in Water on Characteristics of Turbulent Flow in Pipes and Along a Flat Plate," T. C. Hung, M.S. Thesis, Univ. of Iowa, June 1968.
- (2328)
INVESTIGATION OF SURFACE ROUGHNESS.
- (b) Office of Naval Research.
 - (c) Dr. Emmett M. O'Loughlin, c/o CSIRO, Private Bag, Griffith, New South Wales, Australia.
 - (d) Experimental and theoretical; basic research.
 - (e) Development of an improved understanding of the effects of surface roughness on turbulent flow.
 - (f) Completed.
 - (g) Mean-velocity profiles have been measured in free surface flows over beds to which regularly spaced cubes have been attached. Similar wind tunnel experiments have revealed the existence of a thin layer of high intensity turbulence just above the roughness elements. The open channel and wind tunnel profiles exhibit systematic departures from the logarithmic profile. An analytical model for the velocity distribution has been developed on the basis of a distribution of eddy

- viscosity suggested by turbulence measurements.
- (h) "Flow Phenomena Near Rough Boundaries," Emmett M. O'Loughlin and V. S. S. Annambhotla, J. Hydraulic Res., Vol. 7, No. 2, 1969.
- (3739)
EDUCATIONAL FILMS ON THE MECHANICS OF FLUIDS.
(b) National Science Foundation.
(c) Dr. Hunter Rouse.
(g) First five films of series, "Introduction to the Study of Fluid Motion," "Fundamental Principles of Flow," "Flow in a Gravitational Field," "Characteristics of Laminar and Turbulent Flow," and "Form Drag and Lift, and Propulsion," now available from Audiovisual Center, The Univ. of Iowa, Iowa City, Iowa. Sixth film, "Effects of Fluid Compressibility," nearing completion.
- (3740)
HYDRODYNAMICS OF FLUIDS UNDER CONDITIONS OF RAPID ACCELERATION.
(b) Rock Island Arsenal, U.S. Army.
(c) Dr. Enzo O. Macagno.
(d) Theoretical and experimental; basic and applied research.
(e) Analytical and experimental techniques which are applicable to systems involving rapid acceleration of fluids through constrictions, or of solids through fluids.
(f) Completed.
(g) Tests were performed and results compared with those of analytical solutions.
(h) "Motion of a Helical Spring due to Dynamic Loading," D. W. McDougall and E. O. Macagno, IIHR Report 112, Sept. 1968.
"Analysis of the M140 Recoil Mechanism," E. O. Macagno, A. D. Newsham, and T. K. Hung, IIHR Report 113, Oct. 1968.
- (4145)
INTERFACIAL EFFECTS IN FLUID FLOW WITH DENSITY STRATIFICATION.
(b) National Science Foundation.
(c) Dr. Enzo O. Macagno.
(d) Theoretical and experimental; basic research and graduate theses.
(e) Configurations of interface between two layers of fluids of different densities and viscosities.
(g) Analysis under way.
- (5321)
PRESSURE FLUCTUATIONS AT GATED OUTLET WORKS.
(b) U. S. Army Corps of Engineers.
(c) Dr. Frederick A. Locher.
(d) Experimental, basic research.
(e) Effects of shear-layer instability on the spectral distribution and the intensity of pressure fluctuations that may induce gate vibrations are being investigated for various gate and conduit geometries, including effects of cavitation and hydroelastic control.
(f) Completed.
(h) "Some Aspects of Flow-Induced Vibrations of Hydraulic Control Gates," F. A. Locher, IIHR Rept. 116, Feb. 1969.
- (5906)
SCALE EFFECTS IN MODEL TESTS OF ROCK-PROTECTED STRUCTURES.
(b) Iowa Highway Research Board.
(d) Experimental; applied research.
(e) Quantitative definition of the influence of the viscous forces which result in imperfect similarity between the scour behavior of models and prototypes of rock protection around structures.
- Special emphasis has been placed upon observations of the spectral distributions of pressure and velocity fluctuations in the scour hole.
- (f) Completed.
(g) Rate of scour caused by a horizontal jet discharging over a scour pocket filled with spherical glass beads has been measured in geometrically similar flow configurations at six different scales. Particle and conduit dimensions and flow velocities have been adjusted so as to obtain systematic variation of the Reynolds and Froude numbers. Spectra of pressure and velocity fluctuations in rigid-boundary models of the scour flume have been measured to elucidate effects of Reynolds number on the scour behavior. It has been found that the scour behavior is Reynolds number independent if the Reynolds number (based on the jet velocity and particle diameter) is greater than approximately 2500. The normalized spectra are Reynolds number independent. The scour behavior is heavily influenced by the geometrical configuration and turbulence level of the incoming flow.
(h) "Scale Effects in Model Tests of Rock-Protected Structures," S. C. Mehrotra, M.S. Thesis, Univ. of Iowa, June 1967.
"Spectral Analysis of Pressure and Velocity Fluctuations in a Submerged Jet Scour Model," Y. C. Chang, M.S. Thesis, Univ. of Iowa, Feb. 1969.
"Scale Effects in Hydraulic Model Tests of Rock-Protected Structures," E. M. O'Loughlin, S. C. Mehrotra, Y. C. Chang, and J. F. Kennedy, IIHR Rept. 124, Feb. 1970.
- (5908)
EFFECTS OF TURBULENCE AND CURVILINEARITY ON STRATIFIED FLOW.
(b) National Science Foundation.
(c) Dr. Enzo O. Macagno.
(d) Experimental and theoretical; basic research and graduate theses.
(e) The effects of curvilinear patterns and turbulent eddies which tend to change existing stratifications are being investigated.
(g) Conductivity probes and hot-wire anemometers have been used to study patterns of stratification and flow in rotating fluids and in the flow in a bend. Computational models are under development for circulations due to moving boundaries.
(h) "Confined Flows of Homogeneous and Stratified Fluids Induced by a Rotating Disk," J. Aguirre-Pe, M.S. Thesis, Univ. of Iowa, Feb. 1969.
"Numerical Simulation of Stratified Flow," J. Hinwood, Civil Eng. Trans., Australia, Oct. 1968.
"A Numerical Analysis of Circulatory Motion of a Stratified Liquid," T. K. Hung, XIIIth Congr. Intl. Assoc. Hydr. Res., 1969.
- (5909)
ENERGY TRANSPORT AND DISSIPATION IN VISCOUS FLOW.
(c) Dr. Enzo O. Macagno.
(d) Analytical; basic research and graduate theses.
(e) Analysis of laminar steady and unsteady flows from the viewpoint of the energy transport and dissipation.
(f) Completed.
(g) A study of computer solutions of flow in a two-dimensional expansion has shown that the integrated form of the energy equation can be reduced to three terms, the other two being negligible.
- (6351)
FLOW-INDUCED EXCITATION OF LOW-CREST SPILLWAY.
(b) U.S. Army Corps of Engineers.
(c) Dr. Frederick A. Locher.
(d) Experimental; applied research.

- (e) Characteristics of the pressure fluctuations on the spillway face are being measured in order to determine whether these fluctuations may excite vibration of a low-crest spillway on an elastic foundation. The investigation focuses on fluctuations on the spillway crest and at the spillway toe for heads between one and four times the spillway height. Effects of a hydraulic jump are considered briefly.
- (h) Final report in preparation.

(6353) RECESSION CHARACTERISTICS OF IOWA STREAMS.

- (b) Iowa State Water Resources Research Inst.
- (c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics.
- (d) Analytical.
- (e) Recession coefficients of Iowa streams determined for all low-water periods of 10 days or greater duration. Determination of initial flow at the beginning of a recession period is made by stochastic methods relating flow to area, monthly mean temperature, and permeability of the soil in the drainage basin.
- (f) Completed.
- (g) Recession coefficients for each summer month show good consistency and uniformity.
- (h) Bull. 43, Studies in Engineering, Univ. of Iowa.

(6354) SEDIMENT TRANSPORT AND RESISTANCE TO FLOW IN ALLUVIAL CHANNEL BENDS.

- (b) Iowa State Water Resources Research Inst.
- (d) Experimental; basic research.
- (e) Investigation of the effects of channel curvature on the energy dissipation and sediment transport characteristics of alluvial channel flows.
- (g) Experiments are being made in a straight laboratory flume and in a meandering laboratory flume, both partially filled with the same sand. The same mean flow depth and velocity are established in each flume, and the energy gradients and sediment transport rates are measured. It has been found that meandering has a relatively small effect on the energy dissipation rate, but for some flow conditions results in a significant increase in the rate of sediment transport. The evolution of sand wave spectra from an initially flattened bed is also being investigated in the straight flume. It has been found that at small times the spectra exhibit two dominant frequencies, and with the passage of time the variance shifts to the lower frequencies, and the spectra become monotonic. A theoretical model has been developed to explain this behavior.
- (h) "An Analysis of Relationships between Flow Conditions and Statistical Measures of Bed Configurations in Straight and Curved Alluvial Channels," D. Squarer, Ph.D. dissertation, Univ. of Iowa, June 1968.

(6356) NONLINEAR ORDINARY DIFFERENTIAL EQUATIONS IN TRANSPORT PROCESSES.

- (c) Prof. W. F. Ames, Dept. of Mechanics and Hydraulics, Univ. of Iowa.
- (d) Theoretical; basic research.
- (e) Mathematical investigation of equations resulting from similarity analyses of fluid flow, diffusion, heat conduction and other transport processes. Methods of modern algebra are extensively used.
- (g) First integrals of some basic equations have been developed using continuous transformation groups.

(6357)

DEVELOPMENT OF SIMILARITY VARIABLES.

- (c) Prof. W. F. Ames; see (6356) above.
- (d) Theoretical; basic research and graduate theses.
- (e) Development of continuous transformation groups and their invariants (which are the similarity variables) for a variety of fluid problems.
- (g) The natural similarity variables for source diffusion problems and heat transfer in non-Newtonian (power law) flow have been developed.
- (h) "Recent Developments in the Nonlinear Equations of Transport Processes," W. F. Ames, Ind. and Eng. Chem. Fund., Vol 8, 522, 1969.

(6358)

AD HOC METHODS FOR NONLINEAR PARTIAL DIFFERENTIAL EQUATIONS.

- (b) National Science Foundation.
- (c) Prof. W. F. Ames; see (6356) above.
- (d) Theoretical; basic research and graduate thesis.
- (e) Development and utilization of a variety of methods including splitting, functional analysis, general solutions and breakdown theories for waves.
- (g) Large classes of nonlinear hyperbolic equations are obtainable by differentiation of first order equations. The general solutions of these are used to calculate the minimum time for the evolution of solution breakdown (such as shallow water waves breakdown). Applications are shown in shallow water waves, gas dynamics and sound waves.
- (h) "Discontinuity Formation in Solutions of Homogeneous Nonlinear Hyperbolic Equations Possessing Smooth Initial Data," W. F. Ames, Intl. J. Nonlinear Mechanics, in press.

(6359)

TURBULENCE STRUCTURE OF FLOW BEHIND A GRID.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. E. Naudascher, Inst. of Hydromechanics, Univ. of Karlsruhe, 75 Karlsruhe, Germany and C. Farell, Iowa Inst. of Hydr. Research.
- (d) Analytical; basic research.
- (e) Extension of analytical work on grid turbulence contained in the paper: "Flow in the Wake of Self-Propelled Bodies and Related Sources of Turbulence," E. Naudascher, J. Fluid Mech., Vol. 22, Part 4, 1965.
- (f) Completed.
- (g) The deficiencies of the conventional power laws for the decay of grid turbulence, i.e., the discontinuous change from an "initial" to a "final" zone and the undefined range of validity, have been successfully overcome by analyzing grid flow as the plane-source counterpart of flows past point and line sources of turbulence energy. A comparison of the analytical results with published experimental data on turbulence intensity, dissipation length, and integral scale for a great variety of grid geometries and Reynolds numbers revealed good agreement for all downstream zones. Functional relationships between the constants of the resulting analytical expressions and the grid-flow parameters have been deduced to facilitate prediction of turbulence characteristics for any given grid flow.
- (h) "On a Unified Analysis of Grid Turbulence," E. Naudascher and C. Farell, J. Engrg. Mech. Div., ASCE, Vol. 96, EM2, 1970, pp. 121-141.

(6361)

COMPUTATIONAL MODELING OF NON-NEWTONIAN FLOWS.

- (c) Dr. E. O. Macagno.
- (d) Analytical; basic research and graduate theses.
- (e) Unsteady, uniform, and non-uniform non-Newtonian flows are being studied by means of computational

- models based on discretizations of the corresponding differential equations.
- (g) Effects of unsteadiness and of finite disturbances have been analyzed using difference schemes. The effect of nonlinear relations in the constitutive equations has been studied in a shear-thickening fluid.
- (h) "Polynomial Model for the Relaxation Rate of Strain-Stress in Non-Newtonian Liquids," (in Spanish), E. O. Macagno, IIIrd Latin American Hydraulic Congr., IAHR, Buenos Aires, Dec. 1968. "Numerical Experiments on the Stability of a Plane Poiseuille Flow with Finite Disturbances," (in French), A. Pujol, C. R. Acad. Sci., Paris, Vol. 266, March 1968.
- (6362)
TURBULENT MIXING OF DENSITY STRATIFIED LIQUIDS.
- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. C. Farrell.
- (d) Experimental and analytical; basic research and graduate thesis.
- (e) Measurement of the turbulence characteristics of the flow in the wake of a grid towed through a linearly density-stratified liquid, with the aim of determining the effect of the density stratification on the turbulence fluctuations and turbulent mixing, the degree of stratification recovery at various distances behind the grid, and the correlation between turbulent velocity and salinity fluctuations.
- (g) Experiments have been completed with a 1-1/2-in. square-mesh biplane grid made of 1/2-in. square bars and towed at 0.5 fps through a saline solution with a linear density stratification of 1% per foot. The root-mean-square of the longitudinal velocity fluctuations has been found to decrease first, then increase, and, finally, level off with distance downstream from the grid; while the same trend, but with much smaller variations, is exhibited by the root-mean-square value of the vertical velocity fluctuations, the transverse horizontal component of the velocity exhibits the same behavior as in a homogeneous fluid. The cross-correlation between the vertical velocity component and the density fluctuations is a nearly even function at small distances from the grid (as indicated by the values of the quadrature spectra being much smaller than the values of the corresponding cospectra) and becomes a nearly odd function at large distances from the grid (where the quadrature spectra are dominant).
- (6363)
COLLAPSE OF MIXED REGIONS IN DENSITY-STRATIFIED LIQUIDS.
- (b) Office of Naval Research, Dept. of the Navy.
- (c) Prof. William F. Ames and Dr. John F. Kennedy.
- (d) Analytical; basic research.
- (e) Development of a numerical finite difference scheme to describe the profile and internal velocity and pressure distributions of an initial circular region of constant density as it collapses in a surrounding liquid with arbitrary density stratification.
- (f) Completed.
- (g) A numerical solution for the case of linear stratification outside the mixed region and potential flow within it has been obtained. The shape of the initial circular region during collapse is approximately elliptical. The vertical collapse occurs quite rapidly, the height of the mixed region being reduced to half of its initial value in about two characteristic time units (based on the Vaisala frequency) for an external density gradient of 0.0155 ft⁻¹. A method of solution has also been developed for the case of viscous motion within the mixed region, and for the approximately one-dimensional motion that occurs at the later stages of collapse. The numerical method of Chorin for obtaining solutions to the Navier-Stokes equations has been extended to the case of moving boundaries.
- (h) "Wake Deformation in Density-Stratified Fluids," H. I. Padmanabhan, Ph.D. dissertation, Univ. of Iowa, Feb. 1969.
- "Wake Collapse Phenomena in Density-Stratified Liquids," H. Padmanabhan, W. F. Ames, T. K. Hung, and J. F. Kennedy, submitted to Quart. Appl. Math.
- (6364)
FREE SURFACE SHEAR FLOW OVER A WAVY BOUNDARY.
- (b) U. S. Geological Survey.
- (d) Experimental and analytical; basic research.
- (e) Analytical and experimental investigation of the velocity and pressure distributions, surface configuration, and boundary stress distribution of subcritical and supercritical free surface flows over a rigid bed of sinusoidal form.
- (f) Completed.
- (g) Experiments have been completed using two different wavy beds. The predictor developed by Kennedy and Iwasa for the amplitude ratio of and phase shift between the bed and surface waves has been verified. Velocity measurements have revealed that the form of the velocity profiles varies widely along each wave length. Streamwise accelerations are produced by the centrifugal pressure gradients over the depth. Phase shifts have been measured between the variation of the bed shear stress and the bed amplitude. The ranges of occurrence of the various surface configurations have been delineated.
- (h) "Free Surface Shear Flow Over a Wavy Boundary," Y. Iwasa and J. F. Kennedy, J. Hyd. Div., Proc. ASCE, No. HY2, March 1968.
- "A Laboratory Investigation of Free-Surface Wavy-Bed Flow," A. Yuen and J. F. Kennedy, Iowa Inst. of Hydr. Research Tech. Rept., in preparation.
- (6365)
THE STRUCTURE OF TURBULENT FLOW IN A WAVY BOUNDARY CIRCULAR PIPE.
- (b) Office of Naval Research, Dept. of the Navy.
- (d) Experimental and analytical; basic research.
- (e) An experimental investigation of the turbulence array and the velocity, pressure, and shear stress distributions of turbulent flow in a circular pipe whose diameter varies sinusoidally along its length with the aim of establishing the magnitude of the phase shifts between the flow characteristics and the boundary geometry; see (6364) above.
- (f) Completed.
- (g) Experiments in two different wavy-wall pipes, with a mean pipe diameter of five inches, a wave height of 0.220 inches, and wavelengths of 10 and 20 inches, have been completed. The form of the velocity profile has been found to vary radically along a wave length, the value of n in the power-law distribution ranging from about 6 to 22. In a central core both the mean and turbulent quantities appear to be little affected by the boundary waviness; the major effects are confined to the neighborhood of the boundary. The shear-stress variation is shifted about 0.1 wave length upstream with respect to the boundary wave, the exact value depending on the boundary geometry. An analytical model based on continuity principles and irrotationality of the flow along the pipe centerline has been developed for predicting the

- variation of the exponent in the power-law velocity distribution.
- (h) "Turbulent Flow in Wavy Pipes," S. T. Hsu, Ph.D. dissertation, Univ. of Iowa, Aug. 1968.
"Turbulent Flow in Wavy Pipes," S. T. Hsu and J. F. Kennedy, submitted to J. Fluid Mech.
- (6366)
DEVELOPMENT OF A SENSOR FOR SUSPENDED SEDIMENT CONCENTRATION.
- (b) Coastal Engineering Research Center, U.S. Army Corps of Engineers.
- (c) Dr. John Glover and Dr. John F. Kennedy.
- (d) Experimental; applied research.
- (e) Development of a suspended sediment concentration transducer consisting of a small light source and sensor and appurtenant excitation and amplification circuitry. The unit has been designed for measurement of mean and statistical properties of sediment suspensions in steady and unsteady flows.
- (f) Completed.
- (g) An electro-optical system has been developed for Institute measurement of suspended sediment concentration in alluvial channel flows, estuaries, and shoaling waves. The transducer for this system consists of a gallium arsenide diode as a light source and a silicon planar diode as a light sensor. The source light detected by this sensor is modulated by the suspended-sediment in the gap between the source and sensor. The amplifier for the sensor output has been combined on one chassis with signal analyzing circuitry, which includes an analog-to-frequency converter and multiplier circuits. The resulting system is capable of measuring suspended sediment concentrations down to 100 ppm and can compute the mean concentration, the mean square of the concentration fluctuations, and the correlation between sediment concentration and another signal supplied to the system. Exploratory experiments undertaken in a recirculating laboratory flume and a laboratory wave basin proved the practical usefulness of the system.
- (h) "An Electro-Optical Probe for Measurement of Suspended Sediment Concentration," P. K. Bhattacharya, J. R. Glover, and J. F. Kennedy, Proc. 13th Congr. IAHR, Kyoto, Japan, Sept. 1969.
"An Electro-Optical System for Measurement of Mean and Statistical Properties of Sediment Suspensions," J. R. Glover, P. K. Bhattacharya and J. F. Kennedy, IIHR Rept. 120, Oct. 1969.
- (6617)
FRICTION FACTORS FOR FLOW IN SAND BED CHANNELS.
- (b) Agricultural Research Service, U.S. Dept. of Agriculture.
- (d) Theoretical; applied research.
- (e) Development of an improved predictor for depth-discharge relations for all flow regimes in alluvial channels.
- (g) Graphical friction-factor predictors have been developed for the flat bed regime and the ripple and dune regime. The predictor for the flat bed regime is in the format of the classical Moody diagram, with the friction factor being expressed as a function of flow Reynolds number and relative roughness (based on the mean particle diameter). The variation of friction factor with Reynolds number is significantly different for mobile bed channels than for rigid conduits. The additional friction factor resulting from the drag exerted on ripples and dunes is expressed graphically as a function of relative roughness and Froude number based on the mean particle diameter; these variables are arrived at from an analysis of the mechanics of formation of ripples and dunes. Depth discharge relations for several rivers calculated using the proposed technique are in good agreement with measured data.
- (h) "Friction Factors for Flat-Bed Flows in Sand Channels," F. Lovera and J. F. Kennedy, J. Hydr. Div., Proc. ASCE, Vol. 25, No. HY4, July 1969.
"Friction Factors for Flow in Sand Bed Channels," A. M. Z. Alam and J. F. Kennedy, J. Hydr. Div., Proc. ASCE, Vol. 95, No. HY6, Nov. 1969.
- (7368)
SEDIMENT ENTRAINMENT AND SUSPENSION BY SHOALING WAVES.
- (b) Coastal Engineering Research Center, U.S. Army Corps of Engineers.
- (d) Experimental and theoretical; basic research.
- (e) The Iowa Sediment Concentration Measuring System (see (6366) above) is being used to measure the long-term average and fluctuating components of suspended sediment concentration in breaking waves.
- (g) Experiments have been conducted in a laboratory wave tank in which regular waves break on a beach composed of relatively uniform sand. The instantaneous sediment concentration measured by the electro-optical system is fed on-line into a high speed computer. A computer program has been developed which allows determination of: (a) long-term average concentration; (b) a periodic component of the concentration fluctuations; (c) the RMS of the deviation of the concentration from the periodic value, as a function of phase position within the wave. The long-term concentration has been found to vary roughly as a power of distance above the bed.
- (7369)
RIVER FLOW UNDER ICE.
- (b) Rock Island District, U.S. Army Corps of Engineers.
- (c) Dr. John F. Kennedy, and Dr. William W. Sayre.
- (d) Experimental and field investigation; basic and applied.
- (e) Measurement of the velocity and temperature distributions in the Cedar River and the Mississippi River before the onset of winter ice, while the river is ice covered, and during the period of ice breakup. Conduct of laboratory experiments to investigate the effects of year round navigation on the formation of ice jams.
- (g) Measurements of velocity and temperature distributions and ice thickness have been made at regular periods during the winter of 1969-1970. It has been found that the temperature is nearly constant over the depth at any section, but varies laterally across the river width. No supercooling has been observed. The under side of the ice remains smooth while the ice is thickening, but dune-like features occur and the underside becomes rough as the ice melts from below. In the laboratory investigation, a model boat is being passed through the ice cover formed in the low temperature flow facility, and the reformation of the ice in the channel so created is investigated to determine the required frequency of boat passage to maintain an open channel.
- (7370)
DYNAMICS OF ICE COVERED STREAMS.
- (b) National Science Foundation.
- (d) Experimental; basic research.
- (e) An experimental investigation of the kinematics, dynamics, and thermodynamics of the formation and accumulation of river ice, the mechanics of ice-

- cover breakup and/or melting, the characteristics of flow under an ice cover, and of techniques for ice suppression. The investigation is being conducted in a specially designed tilting flume with refrigerated boundaries and inlet section, located in a temperature controlled room. The goal of the study is to develop predictors for the times of onset and dissipation of ice covers, and depth-discharge relations for flow under ice. The mechanics of formation of "ice ripples" at the water-ice interface and their role in determining the friction factor of flow under ice is being investigated experimentally and theoretically. Schemes for suppression of ice formation are being evaluated.
- (g) It has been found that the principal types of ice observed in natural streams can also be formed in the low temperature flow facility.
- (7371)
JET DISCHARGE FROM WATER COOLING TOWERS.
(b) The Marley Company.
(c) Dr. Jung-Tai Lin and Dr. John F. Kennedy.
(d) Experimental; applied research.
(e) The spread of the buoyant plumes ejected from water cooling towers is being investigated over a range of cross wind velocities and for both negative and positive buoyancy. The investigation is being conducted in a large free surface flume, using heated or chilled water for the stack effluent. The recirculation characteristics of the towers are being measured. Temperature measurements are obtained using a specially designed thermistor probe.
- (g) The trajectory, rate of spreading, and the recirculation are more strongly affected by the velocity of the cross wind than by the buoyancy. For each value of the densimetric Froude number there is a value of cross flow which produces a maximum recirculation rate. A new similarity hypothesis for the velocity distribution of turbulent jet wakes has been developed.
- (7372)
THE RELAXATION DISTANCE OF TRANSPORTED SEDIMENT.
(d) Experimental and theoretical; basic research.
(e) Conduct of experiments on the transport of sand through a closed, rectangular cross-section conduit, the top of which is sinusoidal in profile. The profile of the sediment-bed wave produced by the wavy top is being measured for a range of sediment sizes, water temperatures, and flow conditions.
(g) The phase shift of the sediment-bed wave relative to the fixed wave in the conduit roof has been found first to increase and then decrease with water discharge for a given sediment size and water temperature. The phase shift is very sensitive to water temperature. The phase shift between the two waves varies from practically zero to approximately one-half wave-length. The implications of this relaxation distance for the formation of ripples, dunes, and antidunes is being investigated.
- (7373)
MEASUREMENT AND STATISTICAL ANALYSIS OF BED FORMS IN THE MISSOURI RIVER.
(b) U.S. Army Corps of Engineers, Missouri River Division, Omaha District.
(c) Dr. William W. Sayre.
(d) Experimental and analytical, field and laboratory investigation; applied research, for Ph.D. thesis.
(e) Development of instrumentation and methods for acquiring detailed digital data describing longitudinal profiles of alluvial channel beds in large rivers and laboratory flumes. Analysis of digital bed profile data by spectral and other statistical methods, and correlation of resulting statistical descriptors with stream temperature, hydraulic variables and resistance to flow.
- (f) Completed.
(g) Longitudinal profiles of the Missouri River bed were found to be decidedly nonstationary in both the mean and the mean square in most cases. By passing the data through a high pass digital filter it was possible to attenuate the low frequency components, which contribute relatively little to hydraulic resistance, and remove the nonstationarity in the mean. Because of the remaining mean-square nonstationarity, statistical descriptors of bed configuration obtained from frequency distribution analyses of zero-crossing distances and wave amplitudes were found to be more reliable than descriptors obtained from spectral analysis. Attempts to relate these descriptors to hydraulic resistance and stream temperature were only partially successful.
- (h) "Digital Acquisition of Missouri River Bed Profiles," J. R. Glover, IHR Rept. 109, Aug. 1968. "An Electronic Totalizer for Current Meters," J. R. Glover, IHR Rept. 115, May 1969. "Statistical Properties of Bed Forms in Alluvial Channels in Relation to Flow Resistance," V. S. S. Annambhotla, Ph.D. Dissertation, Univ. of Iowa, Aug. 1969.
- (7374)
HYDRODYNAMICS OF FLOW IN THE LOWER URINARY TRACT.
(b) National Institutes of Health.
(c) Dr. Cesar Farell.
(d) Experimental and analytical; basic research.
(e) Analytical and experimental investigation of the flow in the bladder-urethra system, with the aim of developing a theoretical flow model to be used in the analysis and interpretation of micturition data for clinical diagnosis of urinary tract problems.
- (7375)
DISPERSION OF WATER POLLUTANTS IN CURVILINEAR FLOW.
(b) Federal Water Pollution Control Administration.
(c) Dr. E. O. Macagno and Dr. W. W. Sayre.
(d) Experimental and analytical; basic and applied research; graduate thesis.
(e) Study of the separate and joint effects of channel curvature and pollutant buoyancy (positive and negative) on dispersion in open channel flows, with the goal of developing predictors for use in engineering practice.
(g) A meandering tilting flume has been constructed, and systematic experiments on dispersion of neutrally buoyant simulated contaminants are being conducted. Experiments in a small flume have been initiated to study the effect of density bias.
- (7376)
FLUID MECHANICS OF THE SMALL INTESTINE.
(b) National Institutes of Health.
(c) Dr. E. O. Macagno.
(d) Experimental and analytical; basic research, graduate thesis.
(e) Study of the flow induced by the motion of the walls of the small intestine by means of physical and mathematical models. Analysis of records taken in human subjects serve to establish the boundary conditions.
(g) Exploratory models were operated to visualize effects of contractions of the intestinal walls.

- They served as a basis for a first multiple-cell model now under construction.
- (h) "Simulation of Fluid Transport Due to Segmentation in the Small Intestine," E. Lavey, Reports by Research Participants in Science Training, Univ. of Iowa, Summer 1968.

(7377)

MIXING AND TRANSFER PROCESSES FOR HEATED EFFLUENTS IN OPEN CHANNEL FLOW.

- (b) National Science Foundation.
- (c) Dr. William W. Sayre.
- (d) Experimental and analytical; laboratory investigation; applied research.
- (e) Investigation of the processes by which effluent heated water mixes with flowing streamwater, and the excess heat is transferred to surrounding phases of the environment, and finally, how these processes combine to produce a particular temperature distribution pattern in the stream.

(7378)

NATURAL MIXING AND TRANSFER PROCESSES FOR THERMAL LOADS IN STREAMS.

- (b) Office of Water Resources Research, Dept. of the Interior.
- (c) Dr. William W. Sayre.
- (d) Experimental and analytical, laboratory investigation; applied research, for Ph.D. thesis.
- (e) See 1970 Water Resources Research Catalog.

IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY,
Department of Agricultural Engineering, Ames, Iowa
50010. Dr. H. P. Johnson, Professor.

(O17W)

PHYSICAL AND ECONOMIC ANALYSIS OF WATERSHEDS AS RELATED TO SOIL AND WATER CONSERVATION.

See Water Resources Research Catalog, 6.022,
Volume 4.

(O20W)

PHYSICAL, LEGAL AND ECONOMIC ASPECTS OF COSTS AMONG DRAINAGE DISTRICTS.

See Water Resources Research Catalog, 6.0228,
Volume 4.

(106W)

RELATIONSHIP OF HYDROLOGY AND SOILS TO GULLY DEVELOPMENT.

To be listed in Water Resources Research Catalog.

(107W)

STUDY OF SEDIMENT POLLUTION AND MOVEMENT BY ACTIVATION ANALYSIS PRINCIPLES.

To be listed in Water Resources Research Catalog.

- (c) Dr. C. E. Beer.

IOWA STATE UNIVERSITY OF SCIENCE AND TECHNOLOGY,
Department of Engineering Mechanics, Ames, Iowa
50010. Professor Donald F. Young.

(7390)

UNSTEADY FLOW IN A TUBE WITH PRESCRIBED DISCHARGE.

- (b) Iowa Engineering Research Institute.
- (d) Theoretical; basic research; thesis.
- (e) The purpose of the study was to determine the pressure gradient and velocity distribution for the unsteady flow of a liquid through a circular tube when the discharge is specified. Two cases were considered: (1) Starting flow with

constant discharge, (2) starting flow with linearly increasing discharge.

- (f) Completed.

- (g) "Unsteady Flow in a Tube With Prescribed Discharge," W. J. Predebon, T. R. Rogge, and D. F. Young, Trans. ASME, J. Appl. Mech., Vol. 36, No. 3, 635-637, 1969.

(7391)

UNSTEADY HELE-SHAW FLOW.

- (b) Iowa Engineering Research Institute.
- (d) Experimental and theoretical; basic research; thesis.
- (e) The classical problem of steady flow in a Hele-Shaw cell has been extended to pulsating flow. Specific problem studied was harmonically oscillating flow around a circular cylinder. The methods of successive approximations and inner-outer expansions have been used to obtain a solution. Pressure distribution in cell was determined experimentally and compared with the theoretical solution.
- (f) Completed.
- (h) "Unsteady Hele-Shaw Flow," C. C. Shih, Ph.D. Thesis, Iowa State Univ., 1970.

(7392)

EFFECT OF STENOTIC OBSTRUCTION ON FLOW IN TUBES.

- (b) Iowa Engrg. Research Inst.; Public Health Service.
- (d) Experimental and theoretical; basic research.
- (e) Project is concerned with steady and unsteady flow of liquids through circular tubes which contain some type of constriction. Flow characteristics which may be of importance to blood flow through arteries containing stenoses are being studied. These include pressure distribution, laminar separation phenomena, and transition Reynolds numbers for the initiation of turbulence.
- (h) "Effect of a Time-Dependent Stenosis on Flow Through a Tube," D. F. Young, Trans. ASME, J. Engrg. for Ind., Vol. 90, No. 2, 248-254, 1968.
- "Flow Through a Converging-Diverging Tube and Its Implications in Occlusive Vascular Disease," J. H. Forrester, Ph.D. Thesis, Iowa State Univ., 1968.
- "Oscillating Flow Through a Mild Constriction," N. J. Salamon, M.S. Thesis, Iowa State Univ., 1969.
- "Effect of Isolated Protuberance on Flow Through Tubes," D. F. Young and C. C. Shih, Experimental Mechanics, Vol. 9, No. 5, 225-229, 1969.

UNIVERSITY OF IOWA, College of Engineering, Department of Mechanical Engineering, Iowa City, Iowa 52240.
Professor Thomas P. Anderson, Department Chairman.

(6109)

HEAT TRANSPORT IN TURBULENT FLOWS WITH INTERNAL HEAT SOURCES.

- (c) Prof. J. Merle Trummel.
- (d) Experimental; basic research.
- (e) Development of suitable experimental systems permitting measurement of mean temperature distribution; measurements in statistically analogous systems.
- (g) Measurements have been made on one flow geometry with chemical internal heat generation and with an analogous system. Measurements also have been made on circular tube flow using the analogy approach.
- (h) "Analogy Between Steadily Heated Flow and Flow with Internal Heat Generation," Barry K. Hankins,

M.S. Thesis, Univ. of Iowa, Aug. 1965. (Available in Library.)

"Mean Temperature Distribution in Reacting Turbulent Flow with Uniform Internal Heat Generation," J. M. Trummel, Department Rept.

(6111)
LIQUID-VAPOR INTERFACIAL WAVES ON VERTICALLY FLOWING FILMS FORMED BY A CONDENSING VAPOR.

- (c) Dr. Donald L. Spencer.
- (d) Experimental; basic research.
- (e) A study is being made of the stability of the diffusing layer condensation in the presence of non-condensables.
- (g) A stable diffusion layer has not been observed except at extremely low condensation rates. At moderate condensation rates, cells appear to develop in the vapor as it drifts toward the condenser so that non-condensables are carried toward and away from the plate in eddy motion generated by the cells. These cells give rise to vertical undulations on the condensation film. As a result of this strong eddy transport of non-condensable gases, heat transfer coefficients are only slightly reduced even for moderate concentration of non-condensable gases.

(6112)
INTERACTION BETWEEN VORTEX FLOW AND TWO-DIMENSIONAL JET FLOW.

- (c) Professor G. M. Lance.
- (d) Experimental; doctoral thesis.
- (e) A study is being made of the flow characteristics in the finite vortex flow.
- (f) Completed.

(6113)
ON THE INSTABILITY OF TWO-PHASE STAGNATION POINT FLOW.

- (c) Dr. C. J. Chen.
- (d) Experimental and theoretical; basic research.
- (e) The basic set-up of the experiment is a gas jet with variable height, speed and diameter. The measurements of the instability waves are correlated with the theoretical results of various instability mechanisms.
- (f) Completed.
- (g) The preliminary results indicate that the basic parameters to characterize the instability are liquid and gas Reynolds number while Froude and Weber numbers serve only to shift the range of the instability.
- (h) "Low-Temperature Simulation of Hypersonic Melting Ablation and The Observed Wave Patterns," Amer. Inst. Aeronaut. and Astronaut., Paper No. 69-67, 1969, (with S. Ostrach).
"Experimental Investigation of Simulated Hypersonic Melting Waves," M.S. Thesis, Dept. of Mechanical Engrg., Univ. of Iowa, June 1969.

(7393)
SYMMETRICAL AND UNSYMMETRICAL EXPLOSIONS IN A VAPOR-DROPLET MIXTURE.

- (c) Dr. D. C. Chou.
- (d) Theoretical analysis; basic research.

UNIVERSITY OF IOWA, IOWA INSTITUTE OF HYDRAULIC RESEARCH, see IOWA INSTITUTE OF HYDRAULIC RESEARCH.

JET PROPULSION LABORATORY, see CALIFORNIA INSTITUTE OF TECHNOLOGY.

UNIVERSITY OF KANSAS, School of Engineering, Department of Civil Engineering, Lawrence, Kansas 66044.
Professor Yun-Sheng Yu.

The following projects conducted by the Water Resources Research Institute are reported in Water Resources Research Catalog:

(021W)
RIVER BASIN HYDROLOGY (DEVELOPMENT OF A WATER BUDGET MODEL FOR KANSAS STREAMS).

(022W)
EFFECTS OF BANK SEEPAGE ON FLOOD HYDROGRAPHS.

(023W)
THE USE OF ATMOSPHERIC HUMIDITY IN ESTIMATING EVAPOTRANSPIRATION.

(024W)
FURTHER DEVELOPMENT OF THE CLARK METHOD OF UNIT HYDROGRAPH SYNTHESIS.

(027W)
A HYDROLOGIC STUDY OF A MISSOURI RIVER ALLUVIAL AQUIFER.

(108W)
WATER UTILIZATION ASPECTS OF WEATHER MODIFICATION AS APPLIED TO KANSAS.

(109W)
STORAGE OF FRESH WATER IN UNDERGROUND RESERVOIRS CONTAINING SALINE WATER.

(110W)
NUMERICAL MODELING OF UNSATURATED GROUND WATER FLOW.

(111W)
BALANCED STORM DRAINAGE.

(112W)
DISPOSAL OF HEATED WATER THROUGH GROUND WATER SYSTEMS.

(113W)
DETERMINATION OF DISCHARGE-FREQUENCY RELATIONSHIPS FOR SMALL DRAINAGE AREAS.

(6468)
UNSTEADY FLOW PARAMETERS IN HYDRAULIC DESIGN.

- (b) Kansas Water Resources Research Institute.
 - (d) Theoretical and experimental; basic research for doctoral thesis.
 - (e) The inertial effect of flow of water from a reservoir through a short outlet conduit when the valve has been suddenly opened is studied.
 - (f) Completed.
 - (g) A one-dimensional method of solution has been developed to determine the instantaneous average displacement, velocity, and acceleration of liquid in the pipe and the water depth in the reservoir when a valve at the end of the conduit is suddenly opened. Measurements of the instantaneous average fluid displacement in the pipe for different values of the ratio of reservoir diameter to pipe diameter agree very well with the predicted values.
 - (h) "Unsteady Flow in a Reservoir-Conduit System," Yun-Sheng Yu and Mack H. Gray, III. J. Water Resources Res., Vol. 5, No. 3, June 1969.
- (7395)
HYDRAULICS OF NAVIGATION CANALS AND LOCKS.
- (c) Professor John S. McNown.
 - (d) Experimental and theoretical; applied research.

- (e) Study of the interaction of traffic and flow in navigation locks, canals and approaches. Project includes unsteady flow for filling and emptying locks, waves and surges in canals and in approaches to locks, effect of canal and lock configuration on resistance to barges, and effect of flow system on cost and benefit of design. The purpose of the project is to provide information on which to base improved designs and more economic operation on inland waterways.
- (h) "Fluid Mechanics and Lock Design," J. S. McNown, J. Waterways and Harbors Div., ASCE, Vol. 93, No. WW 3, Proc. Paper 5365, Aug. 1967, pp. 9-22. Discussion by J. S. McNown of "On Acceleration of Barge Tows," by J. S. DeSalvo, J. Waterways and Harbors Div., ASCE, Vol. 96, WW 2, May 1970.

(7396)

LONGITUDINAL DISPERSION OF THE LOWER KANSAS RIVER.

- (b) Kansas Water Resources Research Institute.
- (d) Theoretical; applied research.
- (e) The objective of this study is to determine the one-dimensional dispersion coefficients for natural streams based on an analysis of field measurements of concentration-time curves of dye. Particularly, the field data from the main stem reaches of the Lower Kansas River Basin are used.
- (f) Completed.
- (g) An empirical equation for the dye concentration distribution is obtained. From this equation, a dispersion coefficient, which gives the best fit between the computed and the measured concentration-time curves of the dye, is selected as the nearly correct value of dispersion coefficient for the reach. The results show that the dimensionless dispersion coefficient is related linearly on a log-log paper to the Reynolds number of the flow.
- (h) "Longitudinal Dispersion in the Lower Kansas River Basin," Yun-Sheng Yu and M. K. Bansal, Project Completion Report, contribution No. 37, Feb. 1970.

(7397)

TURBULENT DISPERSION AND ATMOSPHERIC REAERATION IN NATURAL STREAMS.

- (d) Theoretical; basic research for doctoral thesis.
- (e) The objectives of this study are: (1) to develop a mathematical model for the turbulent dispersion in natural streams; (2) to determine the reaeration coefficient for natural streams based on the analysis of field data available; (3) to find the relationship between the turbulent dispersion and the atmospheric reaeration, if any.

(7398)

OSCILLATIONS OF LIQUID IN TANDEM TANKS.

- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) The free and forced oscillations of liquid in two circular tanks connected by a pipe are studied both theoretically and experimentally. For the damped free oscillation, the frequency and amplitude of oscillations are determined. For the forced oscillations, the velocity and pressure yield in the system will be determined for different values of frequency and amplitude of the external pressure difference applied to the system.
- (g) Theoretical and experimental results for the damped free oscillations have been obtained. The computed amplitudes of the oscillations of the liquid surface agree very well with the measured values.

UNIVERSITY OF KENTUCKY, College of Engineering, Department of Civil Engineering, Lexington, Kentucky 40506. Don J. Wood, Associate Professor.

(6275)

UNSTEADY FLOW OF SOLID LIQUID SUSPENSIONS.

- (b) National Science Foundation.
- (d) Basic research; M.S., Ph.D. theses.
- (e) Development of basic relationship for wave velocities and magnitudes in suspended flow. Purpose is to be able to analytically describe unsteady suspended flow. Presently studying incipient motion in solid-liquid pipe flow.
- (g) Many basic relationships developed.
- (h) "Unsteady Flow of Solid - Liquid Suspensions," D. J. Wood, T. Y. Kao, J. Engrg. Mech. Div., ASCE, Dec. 1966.
- "Generation and Propagation of Pressure Waves in Two Phase Flow," D. J. Wood and T. Y. Kao, Developments in Theoretical and Appl. Mechanics, Pergamon Press, 1967.
- "Transient Flow of Solid-Liquid Mixtures," D. J. Wood, T. Y. Kao, Proc. Intl. Symp. on Solid-Liquid Pipe Flow and its Application to Solid Waste Collection and Removal, Pergamon Press, 1970.

(6276)

THE INFLUENCE OF STRUCTURAL MOTION ON THE DYNAMIC RESPONSE OF HYDRAULIC FEED SYSTEMS.

- (b) Army Research Office, Durham.
- (d) Analytical and experimental; applied research; M.S., Ph.D. theses.
- (e) Purpose is to integrate structural and fluid dynamic analysis for coupled flow systems.
- (g) Periodic flow systems investigated. Attenuation of waterhammer surge due to line movement shown to be gross effect. Effects of bends and junctions being investigated.
- (h) "The Influence of Structural Motion in the Dynamic Response of Periodic Liquid Flow Systems," D. J. Wood, T. Y. Kao, Conference preprint, ASME - AIAA Structural Dynamics, Structures and Materials Conf., Palm Springs, Calif., 1967.
- "A Study of the Response of Coupled Liquid Flow - Structural Systems Subjected to Periodic Disturbances," D. J. Wood, J. Basic Engrg., ASME, Vol. 90, Series D, No. 4, pp. 532-541, Dec. 1968.
- "Influence of Line Motion on Waterhammer Pressures," D. J. Wood, J. Hyd. Div., ASCE, Vol. 95, No. HY3, pp. 941-959, May 1969.

(7399)

ANALYSIS OF FLOW DISTRIBUTION SYSTEMS.

- (d) Dept. of Defense - Themis.
- (d) Analytical, experimental; applied research; M.S. thesis.
- (e) Purpose is to analyze response of vast distribution network such as capillary bed. Also to model cardio-vascular system to account for blood loss.
- (g) Initial experiment work started; attempting to statistically classify networks.

(7400)

UNSTEADY FLOW THROUGH POROUS MEDIUM.

- (c) T. Y. Kao, Asst. Prof.
- (d) Analytical and experimental, basic and applied research.
- (e) Propagation and attenuation of pressure waves in a porous medium are studied analytically and experimentally. Purpose is to be able to predict the hydrodynamic permeability of a porous medium

- providing the pressure wave characteristic is prescribed.
- (g) Part of the experimental work has been completed and further investigation will be conducted.
- (h) "Pavement Dynamic Permeability Testing," J. W. Hutchinson, T. Y. Kao, and L. C. Pendley, ASTM, May 1969, pp. 159-176.
- (7401)
ENERGY DISSIPATION BY A CROSS-JET CONTROLLED HYDRAULIC JUMP.
- (c) T. Y. Kao, Asst. Prof.
- (d) Analytical and experimental; applied research.
- (e) A two-dimensional cross-jet is utilized to stabilize the hydraulic jump and to increase the energy dissipation by the jump.
- (f) The analytical and experimental results indicate that the hydraulic jump can be stabilized by a cross-jet and better efficiency of energy dissipation is expected if the jet flow is provided by the same source which provides the main-flow. Further investigation will be conducted.
- (g) "Energy Dissipation by a Jet Controlled Hydraulic Jump," presented at ASCE Hydraulics Conf., Minneapolis, Minn., Aug. 19-21, 1970.

LEHIGH UNIVERSITY, Department of Civil Engineering, Fritz Engineering Laboratory, Bethlehem, Pennsylvania 18015. Dr. W. H. Graf, Director, Hydraulics and Sanitary Division.

- (5172)
MEASUREMENT OF SLURRY FLOW BY USE OF 90° ELBOW METER.
- (b) National Bulk Carrier Inc., New York, N.Y.
- (d) Applied research.
- (e) A four-inch 90° elbow meter was calibrated against a magnetic flow meter. A flow range of from 0-1100 gpm was effected in the calibration. Water and fine concentrations of silt-clay-water mixtures are included in the calibration tests. The basic theory of the "elbow meter" is discussed and an empirical mathematical relation between liquid concentration, differential head, and pipe velocity is presented and discussed. The feasibility of use of the elbow meter for flow measurement of slurry type flow is highly possible, but calibration of meter in place is recommended. Also, the viscous properties of the material metered are believed to play an important role in the meter's performance.
- (f) Completed.

- (5173)
SUCTION DREDGING LITERATURE SURVEY.
- (b) Ellicott Machine Corp., Baltimore, Md.
- (d) Applied and basic research.
- (e) This report is a brief review and summary of selected literature pertaining to equipment and methods associated with dredging practice and laboratory studies of dredge pumps. It consists of four parts: (1) Summary and discussion section; (2) selected abstracts; (3) annotated bibliography; (4) bibliography. The discussion section consists of two parts. Part 1 discusses dredging equipment and dredging in general. Part 2 discusses dredge pumps.
- (f) Completed.

- (5552A)
SCOUR OF FLAT SAND BEACHES DUE TO WAVE ACTION.
- See also (5552), Texas A & M University.
- (d) Experimental and theoretical.
- (e) Research requirement of Master's degree.

- (f) Suspended.
- (g) Stability of a horizontal sand bed deposited in shallow water in front of an impervious, smooth seawall under conditions in which the waves have not yet begun to break was investigated. Experimental studies have been performed in a two-dimensional wave channel in an effort to determine the rate, extent, and ultimate amount of scour of the flat sand bed for different conditions of water depth, wave height and length, and slope of sea wall.
- (h) "Scour of Flat Sand Beaches in Front of Seawalls," Stephen C. Ko, Fritz Engrg. Rept. No. 293.5, Lehigh Univ., 1967 (M.S. Thesis).
"Scour of Flat Sand Beaches in Front of Seawalls," 11th Conf. on Coastal Engrg., 1968, London, S. C. Ko and J. B. Herbich.

- (5822)
GAS REMOVAL SYSTEMS ASSOCIATED WITH DREDGE PUMPS.
- (b) District Engr., U.S. Army Engr. Dist., Marine Div., Philadelphia, Corps of Engrs.
- (d) Applied and basic research.
- (e) The overall purpose is to study the effect of gas removal systems on centrifugal dredge pumps. This consists of a program of studies, tests, analysis and reports dealing with ways and means for efficiently removing entrained and dissolved gases from the effluents of dredging with centrifugal pumps in rivers and harbors. The project has been divided into four (4) phases. (a) Literature Search and Formulation of a Test Program. (b) Formulation of Specific Test Setup and Schedule of the Tests with Water. (c) Experimental Study and Analysis of Test Results. (d) Experimental Study with Solid-Water Mixtures (mud) and Analysis of Test Results.
- (h) "Gas Removal Systems, Part I: Literature Survey and Formulation of Test Program," W. P. Isaacs and J. B. Herbich, Fritz Engrg. Lab. Rept. No. 310.3, 1965.
"Gas Removal Systems, Part II: Development of Facility Layout and Formulation of Test Program," A. Shindala, Fritz Engrg. Lab. Rept. No. 310.7, 1965.
"Gas Removal Systems, Part III, Model Study," J. B. Herbich, J. R. Adams, S. C. Ko, Fritz Engrg. Lab. Rept. No. 310.21, 1969.

- (6562)
STUDIES ON THE SETTLING VELOCITY.
- (b) Laboratory project.
- (d) Applied research.
- (e) Model investigation in the determination of the settling velocities of artificial and natural particles.
- (f) Completed.
- (h) "Settling Velocities of Natural Grains," W. H. Graf and E. R. Acaroglu, Bull. Intl. Assoc. Sci. Hydrology, Vol. XI, No. 4, 1966.
"Remarks on the Rubey Equation for Computing Settling Velocities," W. H. Graf and E. R. Acaroglu, VII Intl. Sedimentological Congr. in Great Britain.

- (6564)
THE TRANSPORT OF SOLID SUSPENSION IN CONDUITS.
- (b) Fed. Water Pollution Control Admin., U.S. Dept. Interior.
- (d) Experimental and theoretical; applied research; dissertations.
- (e) The transport phenomenon of solid-liquid flow in a conveyance system is studied. General relationships between flow parameter and sediment transport are established.

- (h) "Designing Conveyance Systems for Solid-Liquid Flow," E. R. Acaroglu and W. H. Graf, Intl. Symp. on Solid-Liquid Flow in Pipes, Univ. of Pennsylvania, March 1968.
 "Homogeneous Suspensions in Circular Conduits," W. H. Graf and E. R. Acaroglu, Proc. ASCE, J. Pipeline Div., No. PL2, 1967.
 "List of Sources of Information on the Pipeline Design, a Discussion," W. H. Graf, Proc. ASCE, J. Pipeline Div., No. PL1, 1968.
 "Sediment Transport in Conveyance Systems, Part 1," W. H. Graf and E. R. Acaroglu, Bull., Intl. Assoc. of Sci. Hydrology, XIII A., No. 2, 1968.
 "Sediment Transport in Conveyance Systems, Part 2," E. R. Acaroglu and W. H. Graf, Bull., Intl. Assoc. of Sci. Hydrology, XIII A., No. 3, 1968.

(6565)

FRICITIONAL EFFECTS IN RIVERS.

- (d) Applied research.
 (e) A careful investigation on the frictional behaviors of various rivers is done.
 (f) Suspended.
 (h) "On the Determination of the Roughness Coefficient in Natural and Artificial Waterways," W. H. Graf, Bull. Intl. Assoc. Sci. Hydrology, IASH, XI, No. 1, 1966.
 "Velocity Distribution and Boundary Roughness in Open Channels," W. H. Graf, Water Power (London), July 1966.

(6566)

THE ELBOW METER, ITS USE FOR MEASURING SOLID LIQUID SUSPENSIONS.

- (b) Laboratory project.
 (d) Applied research; Master's thesis.
 (e) The usefulness of an elbow meter to measure concentration and flow in a liquid-solid mixture is under investigation.
 (h) "Continuous Measurement of Water-Sand Mixtures," W. H. Graf and R. N. Weisman, XIIth Intl. Navig. Congr., PIANC, Paris.
 "Measuring Solid-Liquid Mixtures in Closed Conduits," R. N. Weisman and W. H. Graf, Proc. ASCE, Vol. 94, WW4.

(6567)

HYDRAULIC INVESTIGATION OF THE ST. CLAIR RIVER.

- (d) Applied research.
 (e) The unsteady and steady effects on the river discharge are investigated. Further on the effect of the ice cover is studied.
 (f) Completed.
 (h) "Steady and Unsteady Effects on Discharge in a River Connecting Two Reservoirs," J. A. Liggett and W. H. Graf, 9th Conf. on Great Lakes Research, 1966.
 "The Effect of Ice on the Roughness Coefficient in the St. Clair River," L. Yu, W. H. Graf, and G. Levine, 11th Conf. on Great Lakes Research, 1968.

(7402)

FREE OVERFALL.

- (d) Experimental, applied research; Master's thesis.
 (e) The possibility of using the free overfall as a flow measuring device is investigated.

(7403)

DEVELOPMENT OF IMPROVED DRAINAGE INLETS.

- (b) Commonwealth of Pennsylvania, Dept. of Highways.
 (d) Experimental; applied research.
 (e) Highway drainage inlets currently in use will be tested at a model:prototype ratio of 1:2 to determine the capacity of each for the conditions

in which it is used. This information will be used to develop more efficient drainage inlets.
 (h) "Development of Improved Drainage Inlets, Phase 1: Literature Survey," O. Yucel, G. M. Lee, A. W. Brune, and W. H. Graf, Fritz Engrg. Lab. Rept. No. 364.2 (1969).

(7404)

EFFECT OF FREE STREAM TURBULENCE ON DRAG COEFFICIENT.

- (d) Applied research; Ph.D. dissertation.
 (e) The effect of free stream turbulence on the drag coefficient of a two-dimensional circular cylinder is investigated. The experiments were conducted in a Reynolds number range from 800 to 40,000. The mechanics of wakes were also investigated.

LOCKHEED-CALIFORNIA COMPANY, Oceanics Division, 3380 North Harbor Drive, San Diego, California 92101.
 A. J. Carsola, Division Manager.

(7405)

RESEARCH IN DATA BUOY SYSTEMS.

- (c) Dr. L. Baer.
 (d) Theoretical; applied research.
 (e) Studies concentrated into four tasks, (1) compile a list of available buoy sensors, (2) develop methodology to determine the effect of buoy motions on sampling, (3) investigate sensor failure and reliability, (4) develop a unified theory for the determination of stationary sampling errors.
 (f) (d) above completed.
 (g) (1) Up-to-date compiled list of buoy sensors, (2) a preliminary methodology is finished, (3) temperature probes were analyzed for reliability and causes of failure, (4) computerized program applying the results of a developed theory automatically computes sampling errors for any specified sampling interval and filter.
 (h) "Year-End Progress Report, Data Buoy Research, 1969," Lockheed-California Co. Rept. No. 23244, G. W. Withee, Jan. 1970.
 "Characteristics of Available Sensors for Buoys," Lockheed-California Co. Rept. No. 22756, L. Baer and G. W. Withee, 1969.

(7406)

SAMPLING INVESTIGATIONS FOR SYNOPTIC TEMPORAL OCEANIC OBSERVATIONS.

- (b) U.S. Naval Oceanographic Office.
 (c) Dr. L. Baer.
 (d) Applied research.
 (e) Work concentrates on a methodological sampling scheme for any oceanic parameter. Wind speed was exemplified.
 (g) Nonstationary sampling errors were defined and found to be significant for many realistic examples. Filtering and nonstationarity detection was recommended as a general technique to reduce sampling errors and the effects of filtering were established.
 (h) "Project Sea Sense, 1969, Effects of Stationarity and Nonstationarity on Synoptic Temporal Oceanic Observations," L. Baer and G. W. Withee, Lockheed-California Co. Rept. No. 22981, Nov. 1969.
 (Available from U. S. Oceanographic Office).

(7407)

WIND-WAVE STUDIES.

- (b) Oil company consortium.
 (c) Dr. L. Baer.
 (d) Applied research.
 (e) This work consists of the development of and the

- hindcasting with an operational type wave hindcasting system. The hindcasting is done by computer with a method based on the work of Dr. L. Baer and Prof. W. Pierson of NYU. This method uses a simplified data input technique which allows the method to be of a more practical use, rather than a laboratory experimental tool.
- (f) Hindcasting of six years and over 30 special storms completed; other work continuing.
 - (g) A shortcut wave forecasting technique known as the LOCWAV D 10/30 technique was developed. Results compare favorably with those of the most sophisticated laboratory type computer simulations.
 - (h) Attachment to LAC/000274, Final Report, Wind-Wave Hindcasting for Gulf of Alaska. Oral presentation at the A.G.U. meeting 1969.

LOUISIANA STATE UNIVERSITY AND A AND M COLLEGE,
Department of Civil Engineering, Baton Rouge,
 Louisiana 70803. Dr. F. J. Germano, Department Head.

- (5711)
 FRESH WATER STORAGE IN SALINE AQUIFERS.
- (b) Louisiana Water Resources Research Inst.
 - (c) Dr. Oscar K. Kimbler, Assoc. Prof., Dept. of Petroleum Engrg.
 - (d) Theoretical and experimental; basic research.
 - (e) To determine whether it is theoretically feasible to store fresh water in saline aquifers: injecting fresh water, then removing it from storage. The relative effects of diffusion, dispersion and differences in specific gravity are being studied mathematically and by means of models. The ultimate importance of the work to cities located in flat marshland areas lacking in surface-water storage sites that are underlain by saline aquifers is readily appreciated.

- (5713)
 STUDY OF MEASURES TO BE TAKEN TO ACCOMPLISH PROTECTION OF THE GROUND-WATER SUPPLY OF THE BATON ROUGE AREA FROM DEGRADATION DUE TO SALINE WATER INTO AREA OF OFFTAKE-ENGINEERING ASPECTS.
- (b) Louisiana Water Resources Research Inst.
 - (c) Prof. R. G. Kazmann.
 - (d) Field investigation and theoretical study; applied research and design.
 - (e) Evaluate engineering solutions for providing permanent ground-water supply for Baton Rouge area. Make preliminary feasibility studies of most promising projects.
 - (f) Completed.
 - (h) Report in Bull. 5, La. Water Res. Res. Inst., March 1970.

- (6091)
 A STUDY OF STORM-WATER INLET CAPACITIES.
- (b) Louisiana Dept. of Highways.
 - (c) Prof. William A. Wintz, Jr. and Dr. Yung-huang Kuo.
 - (d) Experimental; applied research and design.
 - (e) To study six existing Louisiana Dept. of Highways storm-water inlets' capacities as a function of widths of flow in the street, roadway grades, and crown slopes on full scale models constructed in the laboratory.
 - (h) Draft of Final Report to La. Dept. of Highways, 3/3/70.

LOUISIANA STATE UNIVERSITY AND A AND M COLLEGE,
Coastal Studies Institute, Baton Rouge, Louisiana
 70803. Dr. S. A. Hsu, Assistant Professor.

- (7408)
 SERIES OF MICROMETEOROLOGICAL STUDIES OF HEAT, MOISTURE, AND WIND PROFILES IN THE COASTAL ZONE.
- (d) Theoretical and field investigation; basic and applied research.
 - (e) From a dynamical meteorological point of view, the coastal region is one type of transitional zone in which the air flow is continuously readjusting itself to a new set of boundary conditions across the shoreline. The line of separation between land and water constitutes a discontinuity in terms of the roughness of the underlying surface, as well as of heat and moisture distribution. There are many deficiencies at present in knowledge of the processes involved. The objective of the project is to provide a basic understanding of heat, moisture, and wind profiles in the coastal zone. The implications of this study are to improve the understanding of wind stress and surface roughness at the air-sea interface of coastal waters; of the internal boundary layer of coastal wind systems; and of aerodynamic roughness criteria in aeolian sand transport.
 - (h) Comments on paper by J. Wu, "Wind Stress and Surface Roughness at Air-Sea Interface," S. A. Hsu, J. Geophys. Res., Vol. 74, No. 23, 1969, p. 5562.
 "Land and Sea-Breeze Fronts Near 50 cm on the Gulf Coast," S. A. Hsu, Bull. Amer. Meteor. Soc., Vol. 50, No. 11, 1969, pp. 880-882.
 "Temperature and Wind Profiles on the Gulf Coast, A Micrometeorological Study," Coastal Studies Bull. No. 4, in press.

LTV RESEARCH CENTER, Ling-Temco-Vought, Inc., P. O.
 Box 6144, Dallas, Texas 75222. Dr. C. S. Wells,
 Senior Scientist.

- (7409)
 THE REDUCTION OF TURBULENT SKIN FRICTION WITH HIGH MOLECULAR WEIGHT POLYMER ADDITIVES.
- (b) The Office of Naval Research, Fluid Dynamics Program, Mathematical Sciences Division.
 - (d) Experimental and theoretical; basic and applied research.
 - (e) The objectives of this program are to (1) develop efficient techniques for diffusing drag-reducing polymers into turbulent boundary layer flows in order to reduce skin friction and (2) to develop theoretical techniques for predicting the drag reduction due to polymers at high velocities.
 - (g) Experimental results of turbulent flow of polymer solutions over rough walls show a delay of the roughness effect on skin friction consistent with the theory of viscous sublayer thickening; a theoretical analysis shows that uniform injection of polymer solutions at the wall is a more efficient process than injection through a slot; recent experiments with solutions diffused from a porous pipe wall confirm the results of the analysis; a symposium on various techniques of reducing viscous drag was held at this laboratory, sponsored jointly by the Office of Naval Research, Naval Ship Research and Development Center and the National Aeronautics and Space Administration.
 - (h) "Use of Pipe Flow Correlations to Predict Turbulent Skin Friction for Drag Reducing Fluids," C. S. Wells, J. Hydronautics, 4, 1, p. 22, (1970).
 "Studies of Viscous Drag Reduction with Polymers"

Including Turbulence Measurements and Roughness Effects," J. G. Spangler, Viscous Drag Reduction, (C. S. Wells, Ed.), p. 131, Proc. Symp. on Viscous Drag Reduction, Sept. 1968, LTV Research Center, Dallas, Plenum Press, 1969.

"An Analysis of Uniform Injection of a Drag-Reducing Fluid Into a Turbulent Boundary Layer," C. S. Wells, Viscous Drag Reduction, (C. S. Wells, Ed.), Proc. Symp. on Viscous Drag Reduction, Sept. 1968, LTV Research Center, Dallas, Plenum Press, 1969.

"Study of the Mechanics of Non-Newtonian Fluids - Final Report," C. S. Wells and J. G. Spangler, LTV Research Center Rept., Contract No. NASw-729, Jan. 1969.

"Viscous Drag Reduction," (C. S. Wells, Ed.), Proc. Symp. on Viscous Drag Reduction, Sept. 1968, LTV Research Center, Dallas, Plenum Press, 1969.

MANHATTAN COLLEGE, Civil Engineering Department,
Bronx, New York 10471. Professor Donald J. O'Connor.

(7410)

DYNAMIC WATER QUALITY FORECASTING AND MANAGEMENT.

(b) Federal Water Pollution Control Admin.

(c) Theoretical, applied research.

(e) Development of mathematical models and analysis techniques for the prediction of the effects of various control measures on water quality in natural waters.

(g) Mathematical model of phytoplankton population dynamics in an estuary. Long-term distribution of chlorides in the Great Lakes. Nitrification in estuaries.

(h) "Maximum Entropy Mixing in Estuaries," D. M. Di Toro, Proc. ASCE, 95, HY 4, July 1969.

"Photosynthesis and the Oxygen Balance in Streams," Donald J. O'Connor and Dominic M. Di Toro, Proc. ASCE, J. San. Engrg. Div., April 1970.

"Modeling Nitrogen and Algal Cycles in Estuaries," R. V. Thomann, D. J. O'Connor, D. M. Di Toro, Tech. Rept., Environmental Engr. & Science Program, Manhattan College.

UNIVERSITY OF MARYLAND, Department of Civil Engineering,
College Park, Maryland 20740. Dr. R. M. Ragan,
Department Chairman.

(7411)

UNSTEADY FLOW IN POROUS MEDIA WITH FREE SURFACE.

(b) Office of Water Resources Research, USDI.

(c) Theoretical; basic research; Ph.D. thesis.

(e) A mathematical model is being developed to determine the position of free surface, flow patterns in the saturated zone, and downstream discharge in terms of the duration and intensity of re-charge for various initial and boundary conditions.

(7412)

SYNTHESIS OF INLET HYDROGRAPHS.

(b) Federal Highway Administration; Maryland State Roads Commission.

(c) Theoretical; applied research; Master's thesis.

(e) A mathematical model which uses the equations of momentum and continuity applied to the overland and gutter flow problems.

UNIVERSITY OF MARYLAND, Institute for Fluid Dynamics and Applied Mathematics, College Park, Maryland 20742.
Dr. L. T. Crane, Institute Director.

(7413)

TWO- AND THREE-DIMENSIONAL JET FLOW.

(b) U. S. Army Material Command, Harry Diamond Labs.

(c) Dr. S. I. Pai, Res. Prof.

(d) Basic theoretical and experimental research.

(e) Analytic and numerical solutions of two- and three-dimensional laminar jet equations with and without free stream and/or wall have been obtained. Experimental measurements of mean velocity profiles of jet of air from various rectangular nozzles at low speed were performed.

(g) In the first two publications, linearized theory of a laminar jet from a nozzle of rectangular cross section into a steady uniform stream with and without walls has been worked out. The spread of the jet is different in different directions. In the third publication, numerical solutions of two-dimensional and axisymmetrical laminar jet with different initial velocity profiles with and without free stream have been obtained. The numerical solutions have been compared with similar solutions, linearized theory and experimental data. An approximate three-dimensional nonlinear jet theory is discussed.

(h) "Three-Dimensional Laminar Jet Mixing," S. I. Pai and T. Hsieh, Phys. Fluids, Vol. 12, No. 4, p. 936, April 1969.

"Linearized Theory of Three-Dimensional Jet Mixing With and Without Walls," S. I. Pai and T. Hsieh, paper No. 69-FLCS-22, ASME, 1969.

"Numerical Solution of Laminar Jet Mixing With and Without Free Stream," S. I. Pai and T. Hsieh, Tech. Note BN-627, IFDAM, Univ. of Maryland, Nov. 1969.

"Investigation of Features of Flow of Three-Dimensional Turbulent Well Jets With and Without Pressure Gradient," John R. Weske, Tech. Note BN556, IFDAM, Univ. of Maryland, June 1968. (Above reports and reprints available from correspondent.)

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Civil Engineering, Ralph M. Parsons Laboratory of Water Resources and Hydrodynamics, Cambridge, Massachusetts 02139. Dr. Arthur T. Ippen, Laboratory Director.
(Address requests for publications to Dr. A. T. Ippen.)

(1609)

BEACH PROCESSES IN THE INSHORE AND FORESHORE ZONES.

(b) Coastal Engineering Research Center, U. S. Army Corps of Engineers.

(c) Prof. C. C. Mei.

(d) Experimental and theoretical; basic research (Doctoral thesis).

(e) Shoaling of periodic surface waves. Slow modulation of finite amplitude waves. Mass transport.

(g) Study of an instrument package for direct measurement of wave kinematics, orbital velocity, etc. Theoretical investigation of finite amplitude wave shoaling and slow evolution of Stokes' waves.

(h) "The Utility of a Hot-Film Sensor and a Directional Vane in the Laboratory Measurement of Velocity Fields in Water Waves," M. M. Kolpak and P. S. Eagleson, M.I.T. Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 118, Dec. 1969.

(3748)

DISPERSION IN POROUS MEDIA IN PUMPING AND RECHARGE OPERATIONS.

- (b) Federal Water Pollution Control Admin.
- (c) Prof. D. R. F. Harleman, Prof. L. W. Gelhar.
- (d) Theoretical and experimental; basic research (Doctoral thesis).
- (e) Development of general numerical and analytical methods for the solution of ground water dispersion problems in a steady flow field. Emphasis is on the development of an efficient finite difference scheme for digital computer application. Applications are in the field of ground water contamination. Longitudinal dispersion in nonuniform flow is analyzed using singular perturbation methods. The effects of density differences on aquifer mixing are being studied analytically and experimentally.
- (g) Approximate analytical solutions have been obtained for dispersion in steady, radial flow from a well and for flow between a recharge and a pumping well. The general finite difference formulation for digital computers has been developed. This program may be used for any steady, two-dimensional dispersion problem. The numerical scheme expresses the convective-dispersion equation in curvilinear coordinates consisting of the streamlines and equipotentials. Analytical results have also been obtained for dispersion in layered, non-homogeneous aquifers. Current research is concerned with cyclic pumping and recharge from the same well and with the effect of small density differences between injected and natural ground water.

(3750)

WAVE FORCES ON OFFSHORE STRUCTURES.

- (b) Shell Development Company.
- (c) Prof. D. R. F. Harleman.
- (d) Theoretical and experimental; applied research (Doctoral thesis).
- (e) Analytical and experimental study of offshore, bottom supported structures in deep water. Object is to determine methods of designing for dynamic response in both periodic and random waves. Platform response in terms of the spectrum of deflection or bending stresses are to be related to the wave spectrum in the case of random waves.
- (f) Completed.
- (g) The structural response of an offshore structure in random waves is developed by a superposition of dynamic response functions for the periodic components of the wave spectrum. For a given wave spectrum, the leg spacing which minimizes the platform deflection has been determined. The analytical methods have been verified by tests on dynamically similar platform models in a wave tank using periodic and random waves. The effect of the direction of approach of the random wave train has also been studied.
- (h) "The Dynamics of Fixed Towers in Deep Water Random Waves," J. H. Nath and D. R. F. Harleman, Proc. A.S.C.E., Vol. 95, No. WW4, Nov. 1969. "Response of a Vertical Cylinder to Random Waves," J. H. Nath and D. R. F. Harleman, Proc. A.S.C.E., Vol. 96, No. WW2, May 1970.

(4648)

A REAL-TIME NUMERICAL MODEL FOR ESTUARINE WATER QUALITY PREDICTION.

- (b) Federal Water Pollution Control Admin.
- (c) Prof. D. R. F. Harleman.
- (d) Theoretical; basic research (Doctoral thesis).
- (e) To formulate and obtain numerical solutions to

the one-dimensional mass transfer equation, including the temporal and spatial variation of tidal velocity and dispersion terms, in a variable area estuary. The solution for concentration distribution, as a function of x and t , is to be obtained by a finite-difference scheme. Comparisons between predicted concentration distributions and field observations of water quality parameters will be made.

- (g) The mathematical model involves a simultaneous solution of the continuity, momentum and mass transfer equations in an implicit finite difference form. The continuity and momentum equations are formulated with appropriate initial and boundary conditions for the tidal motion. The instantaneous values of water surface elevation and tidal velocity form the input to the conservation of mass equations for a number of water quality parameters. Nonlinear tidal friction and acceleration terms are retained in the momentum equation and any number of discrete inflows of pollutant may be introduced into the mass transfer equation. The dispersion term is related to the tidal velocities in the portion of estuaries above the limit of salinity intrusion. Within the salinity intrusion region the dispersion term is obtained from observed salinity distributions. Agreement has been obtained between calculated and observed concentration distributions for a dye dispersion test in the upper Potomac estuary. Additional comparisons with field observations are underway.
- (h) "Numerical Studies of Unsteady Dispersion in Estuaries," D. R. F. Harleman, C. H. Lee, and L. C. Hall, Proc. A.S.C.E., Vol. 94, No. SA5, Oct. 1968.

(4654)

SINGLE AND TWO-PHASE FLOW BETWEEN CONCENTRIC ROTATING CYLINDERS.

- (b) National Science Foundation.
- (c) Prof. A. T. Ippen, Prof. L. W. Gelhar.
- (d) Experimental and theoretical; basic research.
- (e) The research program is directed toward improved understanding of the erosion and suspension process in turbulent shear flow. Experiments are made in a system consisting of two concentric cylinders, each of which rotates producing a centripetal acceleration field which simulates the usual gravitational field.
- (g) Measurements of mean velocity and turbulence have been obtained in the rotating cylinder system of the case with the two cylinders rotating the same direction. The structure of the mean velocity profiles indicates that the flow is influenced by secondary motions generated at the ends of the cylinders. A theoretical analysis of the secondary motion yields results which agree with the observed mean velocity profiles. Currently measurements are being made for the case of counter-rotating cylinders.

(5115)

SYSTEMS METHODOLOGY FOR WATER-RESOURCE PLANNING IN A REGIONAL DEVELOPMENT CONTEXT.

- (b) M.I.T. Inter-American Program in Civil Engineering.
- (c) Prof. F. E. Perkins.
- (d) Theoretical and analytical; basic research.
- (e) Research on the use of mathematical models and systems analysis in planning for comprehensive development of water resources in river basins or other hydrologic units. The relationship of such developments to the social and economic activity of the region in which the unit is lo-

cated is also being considered.

- (f) Completed.
- (g) Final report in process.
- (h) "Optimal Operating Rules for Multi-Reservoir Systems," R. Males, Ph.D. Thesis, Sept. 1968.
- "Mathematical Programming Models Applied to a Water Resource System," J. Poblete, S.M. Thesis, Jan. 1969.
- "Exploratory Integer Models for River Basins," R. M. Hermann, M.I.T. S.M. Thesis, Jan. 1969.

(5117)

ANALYSIS AND SYNTHESIS OF HYDROLOGIC SYSTEMS.

- (b) M.I.T. Inter-American Program in Civil Engineering.
- (c) Prof. P. S. Eagleson.
- (d) Experimental and theoretical; basic research (Doctoral thesis).
- (e) Development of improved analytical techniques for the prediction of the time variation in stream flow at some point in a drainage basin due to a given temporal and areal distribution of precipitation. Development of the means for synthesizing these predictors in the absence of long-term hydrologic records.
- (f) Inactive.
- (g) The laboratory rainmaker is being used in conjunction with a computer simulation of overland flow to study the errors accompanying the unavoidable lack of dynamic similarity in using scale models of surface runoff.
- (h) "Scale Effects in the Physical Modeling of Surface Runoff," V. M. Graveto and P. S. Eagleson, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 120, Feb. 1970.

(5119)

TIDAL, SALINITY AND SEDIMENTATION PROBLEMS IN LAKE MARACAIBO CHANNEL, VENEZUELA.

- (b) M.I.T. Inter-American Program in Civil Engineering; in collaboration with the Instituto Nacional de Canalizaciones and the Universidad del Zulia, in Venezuela.
- (c) Prof. A. T. Ippen, Prof. R. H. Cross.
- (d) Theoretical and experimental; basic research and field investigation (Master's thesis).
- (e) Investigation of flow variables and soil properties controlling rates of erosion and deposition of fine cohesive sediment in a flow field. Purpose of field investigation: To determine the sources and motion of sediment and the time and spatial salinity distribution within the Maracaibo estuary in Venezuela, and to utilize this information for designing remedial works in order to reduce shoaling in the Maracaibo Navigable Channel and control salt water intrusion into Lake Maracaibo.

- (g) The special apparatus developed consists of an annular rotating channel and a counterrotating annular ring placed in the channel and in contact with the water surface. The relative motion of channel and ring generates a uniform turbulent flow field. Experiments with kaolinite clay suspensions have revealed two important properties: (1) The existence of a critical flow velocity for clay deposition. (2) For a given flow, the equilibrium concentration is a constant percentage of the initial sediment concentration in the channel.

Results point out that most of the sediment comes from the Gulf of Venezuela transported near the bottom by tidal and salinity currents. Also a bottom layer at high salinity has been found to exist all the way to the entrance to the lake throughout the year.

(5544)

THERMAL STRATIFICATION IN LAKES AND RESERVOIRS.

- (b) Federal Water Pollution Control Admin.
 - (c) Prof. D. R. F. Harleman.
 - (d) Experimental and analytical; basic research (Doctoral thesis).
 - (e) To develop analytical methods for the prediction of the time dependent thermal structure of lakes and reservoirs. It is also desired to predict the temperature and residence time of water discharged at the reservoir outlet.
 - (g) A theory for the yearly cycle of vertical temperature distribution for a non-advecting lake has been developed which predicts the formation of a surface mixed layer of varying temperature and depth. The results are applicable to deep lakes or shallow ponds with various thermal boundary conditions at the bottom. Experiments were conducted in a laboratory tank using insulation supplied by mercury-vapor and infra-red lamps. Comparisons with field observations in lakes were also made.
- A mathematical model for the yearly cycle of temperature distribution within a reservoir and the outlet water temperature was developed and solved by finite difference techniques. The model accounts for heat input from inflowing streams and solar radiation and heat output from evaporation, radiation at the surface and at the reservoir outlet. The mathematical model was verified by comparison with temperature observations in a laboratory reservoir having artificial insulation and with field data obtained during a full year of operation of Fontana Reservoir (T.V.A.).

Current tests are concerned with the residence time of the reservoir. Dye injection into the inflow and concentration measurements of the outflow are underway.

- (h) "Induced Mixing in a Thermally Stratified Fluid," H. J. Lee, M.I.T. S.M. Thesis, June 1968.
- "Determination of Evaporative Heat Loss Under Laboratory Conditions," M. Markofsky, M.I.T. S.M. Thesis, June 1968.
- "Laboratory and Analytical Studies of the Thermal Stratification of Reservoirs," W. C. Huber and D. R. F. Harleman, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 112, Oct. 1968.
- "Thermal Stratification in Lakes - Analytical and Laboratory Studies," J. M. K. Dake and D. R. F. Harleman, J. Water Resources Res., Vol. 5, No. 2, April 1969.

(5823)

TURBULENCE STRUCTURE OF FLOW IN ROUGH POROUS CONDUITS.

- (b) National Science Foundation.
- (c) Prof. L. W. Gelhar, Prof. A. T. Ippen.
- (d) Experimental and theoretical; basic research (Master's and Doctoral theses).
- (e) The role of turbulence in sediment transport mechanics is being investigated through observations of turbulence structure near rough porous boundaries. Experiments are being made in a ten-inch diameter air flow facility using hot-wire anemometry.
- (g) Detailed measurements of turbulence in a conduit roughened with 0.13-inch diameter spheres have been completed. The influence of boundary porosity is now being investigated in a 12" diameter pipe with a 1" thick layer of porous material on the inside of the pipe. A theoretical analysis of the effects of boundary porosity has been developed.

Very substantial increases in flow resistance and turbulence intensity are produced by the

- porous boundary. Tracer techniques are currently being used to observe the velocity field in the porous boundary.
- (h) "Turbulent Flow in Rough Porous Pipes," R. M. Munoz and L. W. Gelhar, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 109, May 1968.
- (6413)
SURFACE WAVE STUDIES.
- (b) Office of Naval Research, Dept. of the Navy.
- (c) Prof. C. C. Mei, Prof. A. T. Ippen.
- (d) Theoretical; basic research (Doctoral and Master's theses).
- (e) Radiation and scattering of waves by large bodies. Long waves of finite amplitude over uneven bottom.
- (g) Radiation due to oscillation of cylinders; wave scattering and exciting forces on cylinders. Both rectangular and circular shapes are considered. Numerical studies on the nonlinear dispersion of large amplitude waves. Secondary crest phenomenon.
- (h) "Scattering of Surface Waves by Rectangular Obstacles in Waters of Finite Depth," C. C. Mei and J. L. Black, J. Fluid Mech., Vol. 38, pp. 499-511, 1969.
- "The Transformation of a Solitary Wave over an Uneven Bottom," O. S. Madsen and C. C. Mei, J. Fluid Mech., Vol. 39, pp. 781-791, 1969.
- "Shoaling of Waves on the Interface of a Two-Layered Fluid," S. A. Gottschalk, M.I.T. S.M. Thesis, Jan. 1969.
- "Dispersive Long Waves of Finite Amplitude Over an Uneven Bottom," O. S. Madsen and C. C. Mei, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 117, Nov. 1969.
- "Long Waves Over an Uneven Bottom," O. S. Madsen, M.I.T. Sc.D. Thesis, Jan. 1970.
- "Scattering and Radiation of Water Waves," J. L. Black, M.I.T. Sc.D. Thesis, March 1970.
- (6414)
TIDAL COMPUTATIONS IN ESTUARIES AND CANALS.
- (b) Tidal Hydraulics Committee, U.S. Army Corps of Engrs.
- (c) Prof. D. R. F. Harleman.
- (d) Analytical; analysis of field data.
- (e) Development of general digital computer techniques for the calculation of tidal motion in estuaries and sea level canals.
- (f) Completed.
- (g) An explicit finite difference computer program has been developed for the determination of tidal motion in estuaries and canals. The program retains the nonlinear acceleration terms and the nonlinear frictional resistance. Computations have been carried out for the Delaware and Savannah estuaries, Chincoteague Bay, the Cape Cod and Panama sea level canals. In the latter case tidal motion has been computed for canals excavated by both conventional and nuclear cratering techniques.
- (h) "Numerical Computations of Tidal Currents in the Proposed Sea-Level Canal," D. R. F. Harleman and C. H. Lee, Interoceanic Canal Studies Branch, Corps of Engrs., Jacksonville Dist., Fla., May 1967.
- "The Computation of Tides and Currents in Estuaries and Canals," D. R. F. Harleman and C. H. Lee, Committee on Tidal Hydraulics, Corps of Engrs., Tech. Bull. No. 16, Vicksburg, April 1969.
- (6415)
SALINITY INTRUSION IN ESTUARIES.
- (b) Tidal Hydraulics Committee, U.S. Army Corps of Engrs.
- (c) Prof. D. R. F. Harleman, Prof. A. T. Ippen.
- (d) Theoretical and field investigation; applied research (Doctoral thesis).
- (e) Analysis of field data on salinity intrusion and diffusion in estuaries. Development of methods of predicting changes in longitudinal distribution of salinity due to changes in fresh water flow rate, channel depth, tidal prism, etc. Investigation of shoaling phenomena related to salinity intrusion.
- (g) Data from a laboratory salinity flume at W.E.S. has been analyzed on a two-dimensional basis. A correlation between bottom velocity (averaged over a tidal cycle) and salinity distribution results in the prediction of a "null point" where shoaling is usually heavy. Changes in the longitudinal location of the "null point" may be predicted due to changes in estuary geometry or flow. Current studies are concerned with the real-time analysis of salinity intrusion during a tidal period with the objective of developing a method of predicting intrusion which is independent of field observations.
- (h) "Salinity Intrusion Effects in Estuary Shoaling," D. R. F. Harleman and A. T. Ippen, Proc. A.S.C.E., Vol. 95, No. HYL, Jan. 1969.
- (6421)
OPTIMUM LINEAR SYNTHESIS IN URBAN HYDROLOGY.
- (b) Office of Water Resources Research, U.S. Dept. of the Interior.
- (c) Prof. P. S. Eagleson.
- (d) Theoretical; basic research (Master's and Doctoral theses).
- (e) Development of a digital computer simulation of surface runoff on urban catchments. The simulation will be used to investigate (1) analytical errors due to lumping of distributed systems; (2) analytical errors due to the assumption of linear behavior; (3) experimental errors due to sampling of areally variable rainfall, and to develop an optimum linear model for use in hydraulic design.
- (g) A distributed, finite-element type simulation of surface runoff is developed for digital computer application. The simulation is used to investigate (1) analytical errors due to lumping of distributed systems; (2) analytical errors due to the assumption of linear behavior; (3) experimental errors due to sampling of areally variable rainfall, and to develop an optimum linear model for use in hydraulic design.
- (h) "Streamflow Record Length for Modelling Catchment Dynamics," W. M. Grayman and P. S. Eagleson, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 114, Feb. 1969.
- "A Distributed Linear Representation of Surface Runoff," W. O. Maddaus, and P. S. Eagleson, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 115, June 1969.
- (6422)
A PROBLEM-ORIENTED LANGUAGE FOR HYDROLOGIC ANALYSIS.
- (b) Office of Water Resources Research, Dept. of the Interior.
- (c) Prof. F. E. Perkins.
- (d) Theoretical; basic and applied research (Master's and Doctoral theses).
- (e) Development of a problem-oriented computer language for a variety of hydrologic analyses including steady and unsteady open channel hydraulics, hydrologic data analyses, and rainfall-runoff processes.
- (g) Numerical procedures for steady and unsteady

open-channel flow problems have been the subject of detailed error analysis leading to the establishment of criteria for adoption of a method and selection of optimum increment sizes.

(7414)

Thermal Pollution Associated with Electric Power Generation.

- (b) Federal Water Pollution Control Admin.
- (c) Prof. D. R. F. Harleman.
- (d) Analytical and experimental; basic and applied research (Doctoral thesis).
- (e) (1) An investigation of two-layer thermal stratification in an adjacent waterway resulting from a condenser water outlet channel designed to minimize mixing of the heated effluent; (2) an investigation of complete mixing of heated condenser water and river water by means of a multi-port diffuser pipe; (3) an investigation of local mixing and dilution produced by heated surface jets discharging into an adjacent waterway.
- (g) The first two phases have been completed. Design procedures have been developed for non-mixing condenser water outlet channels and for skimmer walls to prevent recirculation. Observations on a complete mixing diffuser have been made for steady river flow and for unsteady flows produced by peak-load operation of a downstream hydroelectric plant. At low river discharges an upstream wedge of mixed temperature water is formed while downstream of the diffuser complete mixing is obtained.

The third phase is concerned with the development of a theoretical basis for predicting the temperature distribution in a heated jet as a function of initial densimetric Froude number, jet aspect ratio, ambient cross flow and surface heat loss.

- (h) "Thermal Diffusion of Condenser Water in a River During Steady and Unsteady Flows," D. R. F. Harleman, L. C. Hall and T. G. Curtis, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 111, Sept. 1968.
- "A Model Study of Proposed Condenser Water Discharge Configurations for the Pilgrim Nuclear Power Station at Plymouth, Massachusetts," D. R. F. Harleman, and K. D. Stolzenbach, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 113, Nov. 1968.
- "Mechanics of Condenser Water Discharge from Thermal Power Plants," D. R. F. Harleman, Ch. 5 in Engineering Aspects of Thermal Pollution, (P. Krenkel and F. Parker, Eds.), Vanderbilt Univ. Press, 1969.

(7415)

Operational and Research Uses of Radar in Hydrology.

- (b) National Severe Storms Lab., Environmental Science Services Admin.
- (c) Prof. P. S. Eagleson.
- (d) Theoretical and field investigation; basic research (Doctoral thesis).
- (e) The value of better rainfall information in flood forecasting, water yield and other hydrologic problems is to be determined. The advantages of using radar instead of or in conjunction with raingages is being examined.
- (g) Radar is most effective in measuring spatially varying precipitation over large areas but is relatively inaccurate in determining point rainfall intensities. Raingages require dense networks in order to determine areal variability. The conjunctive use of radar and raingages is found to be potentially beneficial in improving precipitation measurements.

A simulation of catchment response to areally distributed rainfall is used, with a stochastic simulation of the rainfall and with the known accuracy of various rainfall measuring systems, to determine under what circumstances the use of weather radar leads to improved flood forecasting.

- (h) "A Review of the Accuracy of Radar and Raingages for Precipitation Measurement," W. M. Grayman and P. S. Eagleson, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 119, Feb. 1970.

(7416)

Multiple Objective Analysis of the Big Walnut Project.

- (b) Joint Water Resources Council-Laboratory Project.
- (c) Prof. D. C. Major.
- (d) Applied research.
- (e) Multiple objective public expenditure theory is applied to a Corps of Engineers proposed project.
- (g) A net benefit transformation curve for national income and acres of ecological area has been derived.

(7417)

Multiple Objective Analysis of the Proposed Red River Dam, Kentucky.

- (b) Center for Advanced Engineering Studies, M.I.T.
- (c) Prof. D. C. Major.
- (d) Field investigation (Master's thesis).
- (e) Multiple objective decision making for the proposed Red River Dam, Kentucky, will be investigated.

(7418)

Application of Laser Technique to Sediment Concentration Measurement.

- (c) Prof. A. T. Ippen, Prof. B. B. Sharp.
- (d) Theoretical and experimental; basic research.
- (e) Counting of particle passage at given points of the flow field of mixture of sediment and water.
- (g) Instrument development involving optical and laser beam components to measure sediment concentrations in open channel or closed conduit flow at any point in flow field.

(7419)

The Absolute Concentration of Suspended Sediment in Turbulent Streams.

- (d) Theoretical and experimental; basic research.
- (e) Definition of interaction of turbulent shear flow with sedimentary particles in suspension in open channels.
- (g) A new tilting flume recirculating the sediment-liquid mixture in various concentrations has been built. It is 64 feet long, 18 inches wide and 10 inches deep (maximum). The discharge can be varied up to 3.5 cfs. Precise measurements of sediment concentrations and velocity distributions will be made in order to explore the validity of semi-theoretical relations for the absolute suspended load and the related modifications of the velocity profiles.
- (h) "The Absolute Concentration of Suspended Sediment in Turbulent Streams," Nelson Ordóñez-C., M.I.T. Ph.D. Thesis, June 1970.

(7420)

Comparative Scour Patterns for Air and Water Jets.

- (d) Experimental; basic research.
- (e) Interaction of a two-dimensional jet with a bed composed of sediment particles of different sizes.
- (g) Erosion patterns generated by jets of air and of water are studied in the specially built flume. The purpose is to compare similarities and differences of the scour patterns. The analysis of the results is done on the basis of the various

dimensionless parameters governing sediment transport for various particle sizes and jet velocities in air and water.

- (h) "A Comparative Study of Sediment Transport by Water and Air Currents," Francisco Coronado del Aquila, M.I.T. Civil Engineer's Thesis, June 1970.

(7421)

MANAGEMENT ASPECTS OF THERMAL POLLUTION.

- (b) Urban Systems Laboratory, M.I.T.
(c) Prof. D. H. Marks.
(d) Theoretical; applied research.
(e) Optimal investment models are described for choosing location and equipment for thermal power generation subject to economic and environmental constraints. Models are designed to give sensitivity information and an approximation of the costs to meet stream temperature standards.
(g) Optimal investment models have been proposed and are in a development stage.

(7422)

BOGOTA RIVER STUDY.

- (b) M.I.T. Inter-American Program in Civil Engineering.
(c) Prof. F. E. Perkins.
(d) Theoretical and analytical; basic research.
(e) Use of mathematical models as an aid in the planning for optimal use of water resources in the Bogota River Basin of Colombia. The effectiveness and relative merits of linear deterministic, linear stochastic, and simulation models will be evaluated.
(g) A chance-constrained linear programming model coupled with an optimum linear hydrologic predictor has been developed and is currently being tested.
(h) "Modele de Programmation Lineaire pour la Planification de L'Irrigation," F. E. Perkins, R. M. Hermann, XI Journees de L'Hydraulique, Societe Hydrotechnique de France, Sept. 1970.

(7423)

WATER WAVE INTERACTION WITH COASTAL STRUCTURES.

- (b) Coastal Engineering Research Center, U.S. Army Corps of Engrs.
(c) Prof. R. H. Cross, III.
(d) Theoretical and experimental; applied research (Master's and Doctoral theses).
(e) Present efforts are directed towards studying the mechanisms by which water waves are transmitted past breakwaters.
(g) A theory for water wave transmission through a permeable structure has been developed.

(7424)

OIL SLICK CONTAINMENT AND COLLECTION.

- (b) Federal Water Pollution Control Admin.
(c) Prof. R. H. Cross, III.
(d) Experimental and theoretical; applied research (Master's theses).
(e) Efforts are presently directed towards understanding the effects of currents on oil slick booms, and the dynamics of collector sweeps.

(7425)

LONG ISLAND GROUNDWATER HYDROLOGY.

- (b) New York State Board of Health.
(c) Prof. L. W. Gelhar, Prof. D. R. F. Harleman.
(d) Experimental and theoretical; applied research (Master's and Doctoral theses).
(e) A vertical Hele-Shaw model is being used to simulate the unsteady aquifer response and a salt water intrusion under conditions of increased pumping.
(g) Model simulations of water table response and

salt water intrusion have been obtained for alternative methods of groundwater utilization on Long Island. Analytical predictions of salt water intrusion and dispersive mixing between the fresh and salt water have been developed.

(7426)

EFFECTS OF TOPOGRAPHY OR EARTHQUAKES ON STORM-GENERATED WATER WAVES.

- (b) National Science Foundation.
(c) Prof. C. C. Mei, Prof. A. T. Ippen.
(d) Theoretical; basic research (Master's and Doctoral theses).
(e) Random water waves scattered by large near-shore structures, or topography changes.
(g) Scattering by a submerged storage tank, scattering cross-sections, and forces and movements. Mass transport in random waves.
(h) "Scattering of a Monochromatic Wave by a Vertical Circular Cylinder," M. C. G. Bray, M.I.T. S.M. Thesis, Feb. 1970.

(7427)

PLANNING FOR CAPACITY EXPANSION OF WATER DISTRIBUTION NETWORKS.

- (b) Office of Water Resources Research, Dept. of the Interior.
(c) Prof. J. C. Schaake, Jr.
(d) Theoretical; applied research (Doctoral thesis).
(e) The objective is to improve the methodology which is used to plan capacity expansions of urban water distribution systems to meet anticipated future water needs. The same models will be developed which can be implemented with the kinds of information that are available in most U.S. cities. The planning problem is to decide what facilities such as pipes, tunnels, and reservoirs should be constructed at different future times.
(g) The strategy of this study has been first to define an optimality criterion for ranking alternative investment opportunities and then to formulate a mathematical programming model for solving the optimal investment problem. The least cost optimality criterion leads to a non-linear mathematical programming problem for which no computational methods exist that guarantee an optimal solution. Other existing techniques that yield good solutions are computationally inefficient. The strategy taken has been to modify the least cost problem so that linear programming could be applied to achieve a solution to the modified form of the problem. The resulting linear programming model may be used to determine the pipe diameters and must be added to an existing system to satisfy given sets of water requirements that are expected to occur at given future times.
(h) "Linear Programming and Dynamic Programming Application to Water Distribution Network Design," J. C. Schaake, Jr. and D. Lai, M.I.T., Dept. of Civil Engrg., Hydrodynamics Lab. Rept. No. 116, July 1969.

(7428)

WATER RESOURCE PLANNING FOR NEW COMMUNITIES.

- (b) Urban Systems Laboratory, M.I.T.
(c) Prof. J. C. Schaake, Jr.
(d) Theoretical; applied research.
(e) The objective of the study is to identify and describe the interrelationships between water resources and new community development. The research will focus on some specific points of major importance. This work is being carried on as part of a larger investigation of techniques for new community planning.

(7429)

MATHEMATICAL WATER QUALITY PLANNING MODELS.

- (b) Urban Systems Laboratory, M.I.T. and Education Research Center, M.I.T.
- (c) Prof. J. C. Schaake, Jr.
- (d) Theoretical; applied research.
- (e) Several mathematical models are being developed and applied to determine optimal schemes for investing in facilities to control water quality in the Boston Harbor. Feasible facilities include storage space for storing combined sewer overflows, treatment facilities for treating municipal and industrial wastes (treated, untreated, and combined sewer overflows) throughout the harbor. The models include a mathematical programming model for determining optimal investment schemes, a waste transport model for estimating coefficients for the mathematical programming model, a tidal current model for estimating currents for the waste transport model, a combined sewerage system model for representing the overflows of combined wastes, and a hydraulic systems model for computing hydrographs of surface runoff.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Mechanical Engineering, Cambridge, Massachusetts 02139. Professor A. H. Shapiro, In Charge, Fluid Mechanics Laboratory.

(6105)

STUDY OF ATMOSPHERIC DISPERSION.

- (b) National Air Pollution Control Admin.
- (c) Prof. James A. Fay and Prof. David P. Hoult.
- (d) The project consists of laboratory experiments, field investigations, and studies of semi-empirical theories.
- (e) Aerodynamic motion of buoyant plumes rising from high smoke stacks is the subject under investigation. The purpose of the research is to find simple, accurate methods for computing the trajectory of the plumes, and the ground level concentration of pollutants due to the smoke stack.
- (g) A good correlation of field experiments and laboratory data has been achieved based upon simple entrainment models.
- (h) "A Theory of Plume Rise Compared with Field Observations," D. P. Hoult, J. A. Fay, and L. J. Forney, *AFCA J.*, 19, No. 8, 585-590, Aug. 1969.

(6106)

DEVELOPMENT OF INTRA-AORTIC BALLOON PUMPING.

- (b) National Heart Institute, National Insts. of Health.
- (c) Prof. Ascher H. Shapiro and Prof. Michel Y. Jaffrin.
- (d) Experimental and theoretical; applied research, doctoral thesis.
- (e) This is a method for assisting patients in heart failure. It provides, with only minor surgery, a prosthetic ventricle in series with the left ventricle, and is capable of reducing the work load on the heart. A balloon is inserted into the aorta, at the end of a catheter, through either the carotid or femoral artery. The proximal end of the catheter is connected to a gas source. By inflating and deflating the balloon in proper phase with the heart cycle, the maximum pressure against which the heart pumps may be reduced and the workload of the left ventricle may be partially transferred to the aortic balloon.

Regardless of the state of the art of heart re-

placement, a simple procedure of assisting the heart will always be needed, whether to assist the patient's own heart, until it can recover, or until the patient's condition improves sufficiently so that he can undergo any necessary surgery, or as a permanent or semi-permanent prosthetic device.

(f) Completed.

- (g) A general theory for counterpulsation heart assist devices has been developed for the arterial system represented as a network of tapered elastic tubes. A mock loop suitable for testing intra-aortic balloons has been studied. A longitudinally constrained balloon has been designed which overcomes the "bubble blowing" phenomenon. It is found advantageous to inflate and deflate the balloon during heart diastole.
- (h) "Fluid Mechanics of Intra-Aortic Balloon Counterpulsation," Proc. Artificial Heart Program Conf., Washington, D.C., June 1969, U.S. Dept. of Health, Education and Welfare, pp. 505-522.
- "Motion Produced by Combination of Gravity and Pressure Differential When a Gate in a Tank of Liquid Is Broken," W. S. Chiu, M. Y. Jaffrin, and A. H. Shapiro, *J. Fluid Mech.*, 43, 2, 1970.
- "The Dynamics and Fluid Mechanics of the Intra-Aortic Balloon Heart Assist Device," T. A. McMahon, V. S. Murthy, C. Clark, M. Y. Jaffrin, A. H. Shapiro, *Fluid Mechanics Lab. Publ. No. 69-11*, Dept. of Mech. Engrg., M.I.T., Cambridge, Mass.

(6108)

RESEARCH ON PERISTALTIC PUMPING.

- (b) Office of Naval Research.
- (c) Prof. A. H. Shapiro and Prof. M. Y. Jaffrin.
- (d) Experimental and theoretical research; doctoral thesis.
- (e) The pumping action of peristaltic waves moving along a flexible tube is studied with special attention given to the presence of reverse flow. A reverse flow may explain how infection passes from the bladder to the kidney in a direction opposite to the main urine flow. The influence of wave shape and tube geometry on the pumping are also investigated.
- (f) Completed.
- (g) A theory has been completed when the ratio of wavelength to tube diameter is large and the Reynolds number is zero. An experimental apparatus has been built to check the theory and its validity range. The predicted flow-pressure gradient relation is in good agreement with the experimental values for Reynolds numbers less than one. Both theory and experiment show the presence of a reverse flow near the walls. A theoretical model of ureteral function has been set up which describes correctly the physiological observations.
- (h) "Peristaltic Pumping with Long Wavelengths at Low Reynolds Number," A. H. Shapiro, M. Y. Jaffrin, and S. L. Weinberg, *J. Fluid Mech.*, 37, 799-825, (1969).
- "Inertial and Streamline Curvature Effects on Peristaltic Pumping," M. Y. Jaffrin, to be published in Proc. SES Meeting, Washington Univ., St. Louis, Missouri, Nov. 1969.
- "An Hydrodynamical Model of Ureteral Function," S. L. Weinberg, M. Y. Jaffrin, and A. H. Shapiro, to be published in Proc. Workshop on Hydrodynamics of the Upper Urinary Tract, Chicago, Oct. 1969. Reported in Vol. 4, *WRRG*, No. 3.079.

(7430)

- COUNTERWASHERS FOR FREEZE-DISTILLATION DESALINATION.
- (b) Office of Saline Water, U.S. Dept. of the Interior.
- (c) Prof. Ronald F. Probststein.
- (d) Experimental and theoretical; applied research.
- (e) To develop from a hydrodynamic point of view a theoretical and experimental understanding of counterwashers of the type used in washing brine from ice crystals in order to determine criteria for the design and construction of higher performance columns than presently exist. Preliminary hydrodynamic studies, based on Darcy's Law, have been applied to the calculation of the displacement of the brine by fresh water from the interstices of the ice plug formed in the column. Theory indicates the main difficulty in obtaining large net production rates of fresh water in the counterwasher results from the fact that large quantities of brine must be discharged through the screens, and before reaching the screens this brine must flow through the packed ice bed which presents a large resistance to the flow. The production rate is found to increase with decreasing the ice plug length below the screens and the back pressure at the screens, and increasing ice crystal size, pressure at bottom of plug, the wall friction. Experiments on a simulated counterwasher will be carried out with polyethylene beads and ice crystals to investigate the effects predicted. The theory will also be extended to determine an optimum design counterwasher from economic and dynamic considerations.

(f) Completed.

- (g) A hydrodynamic theory for flooded counterwashers has been developed and the similarity parameters governing the system have been found. Laboratory scale experiments carried out on washing brine from plastic particles confirm the theoretical predictions and demonstrate the feasibility of obtaining high crystal washing rates.
- (h) "An Analysis of Counterwashers for Freeze-Distillation Desalination," J. Schwartz and R. F. Probststein, *Desalination*, **4**, 5-29, (1968). Reply to Comments on "An Analysis of Counterwashers for Freeze-Distillation Desalination," Josef Schwartz and Ronald F. Probststein, *Desalination*, **6**, 239-266, (1969). Reported in Vol. 4, WRRR, No. 3.0279.

(7431)

- THE ELECTROHYDRODYNAMICS OF ELECTRODIALYSIS SYSTEMS.
- (b) Office of Saline Water, U.S. Dept. of the Interior.
- (c) Prof. Ronald F. Probststein and Prof. Ain A. Sonin.
- (d) Experimental and theoretical; applied research.
- (e) The objective of the proposed work is to develop from an electrohydrodynamic point of view a theoretical and experimental understanding of the electrodialysis process for saline water conversion. In the present research the properties of the membranes will be taken to be given and the objective will be to determine theoretically and experimentally the potential, concentration, and flow field distributions as well as the appropriate scaling and similarity parameters. The theoretical distributions will be determined for different geometrical and flow conditions and will take into account effects of water dissociation, several ionic species, finite thickness and partially selective membranes as well as unsteady operating conditions. Based on the scaling and similarity parameters obtained from the theoretical work, laboratory scale electrodialysis cells will be investigated with the aim of measuring both overall flow and field quantities as well as

detailed potential and concentration distributions which may then be compared with the theoretical results. An important feature of the work will be to show the need to take into account the developing nature with distance along the channels of the electric and concentration field distributions as well as their spatial interactions. On the basis of the results obtained an appropriate redesign of electrodialysis units for more efficient and economical operation will be undertaken both theoretically and in the laboratory.

- (g) A hydrodynamic theory of electrodialysis has been developed for steady laminar flow between plane, parallel membranes. The modeling of the system is found to be governed by four basic similarity parameters. Laboratory experiments presently in progress confirm the theoretical predictions.
- (h) "A Hydrodynamic Theory of Desalination by Electrodialysis," Ain A. Sonin and Ronald F. Probststein, *Desalination*, **5**, 293-329, (1968). Reported in Vol. 4, WRRR, No. 3.0280.

(7432)

THE INTERNAL HYDRODYNAMICS OF POROUS MEMBRANES FOR REVERSE OSMOSIS.

- (b) Office of Saline Water, U.S. Dept. of the Interior.
- (c) Prof. Ronald F. Probststein and Prof. Ain A. Sonin.
- (d) Experimental and theoretical; applied research.
- (e) The objective of the proposed work is to develop a mathematical model for the internal hydrodynamics and electrochemistry of a relatively high porous salt rejecting reverse osmosis membrane through which initially saline liquid (which may contain particulate suspensions) is forced at a high flow rate, and to define the critical scaling parameters which govern the process and characterize such membrane/flow systems. The scaling parameters will provide a rational basis for comparing the performance of different porous membrane systems and possibly provide a rational basis for constructing optimum membranes. Model experiments and data correlations will be carried out to check the theory and appropriateness of the scaling parameters derived.

(7433)

TURBULENCE PRODUCTION IN HUMAN ARTERIES HAVING ATHEROSCLEROSIS.

- (b) National Dairy Council.
- (c) Prof. C. Forbes Dewey, Jr. and Dr. Robert S. Lees.
- (d) Clinical and theoretical investigation.
- (e) Heart sounds, murmurs, and audible bruits produced by peripheral arteries are familiar to every physician and convey much information about his patients' cardiovascular health. In present clinical practice, the information obtained by listening to these sounds is limited to pattern recognition; no systematic or scientific basis exists for quantitative interpretation, although the "primae causae" of the various sounds are quoted widely in medical textbooks. The simplest pathological circumstance leading to cardiovascular sound is that of a partially-occluded peripheral artery. Such points of stenosis occur frequently in patients with advanced atherosclerosis. We have performed a frequency analysis of these sounds, and correlated the spectra with a fluid-mechanical model of turbulence produced by jet-like flow past the occlusion. On the basis of these results, significant information can be obtained concerning the diameter of the vessel, the degree of occlusion, and the local flow velocity. This non-invasive technique appears to have widespread

- application in the study of arterial disease.
- (g) "How to Listen to Arteries," J. Fredberg, R. S. Lees, and C. F. Dewey, Jr., Paper No. 70-144, AIAA 8th Aerospace Sciences Meeting, New York, Jan. 1970.
- "Phonoangiography: A New Noninvasive Diagnostic Method for Studying Arterial Disease," R. S. Lees and C. F. Dewey, Jr. (in press).
- (7434)
ENGINEERING PROBLEMS ASSOCIATED WITH OIL POLLUTION.
(b) Federal Water Pollution Control Admin. and Coast Guard.
- (c) Prof. David P. Hoult and Prof. James A. Fay, Dept. of Mech. Engrg., Prof. Jerome H. Milgram, Dept. of Nav. Arch., and Prof. Ralph H. Cross III, Dept. of Civ. Engrg.
- (d) The project includes experimental and theoretical investigations of problems associated with containing oil on the sea, collecting it and predicting rate of spread. A number of projects are underway leading to Master's and Doctor's theses.
- (e) The purpose of the project is to find ways to contain and collect and predict the rate of spread of oil spilled on the sea.
- (h) "Containment and Collection Devices for Oil Slicks," David P. Hoult, Fluid Mechanics Lab. Publ. No. 69-8, 1969, M.I.T., Cambridge, Mass.
- "The Spread of Oil Slicks on a Calm Sea," James A. Fay, Fluid Mech. Lab. Publ. No. 69-6, M.I.T., Cambridge, Mass.
- "Oil on the Sea," David P. Hoult (Ed.), Plenum Press, New York, 1969.
- "Containment of Oil Spills by Physical and Air Barriers," David P. Hoult, presented at AIChE Meeting, Puerto Rico, 1970.
- "The Spreading and Containment of Oil Slicks," David P. Hoult, presented at AIAA 3rd Fluid and Plasma Dynamics Conf., Los Angeles, 1970.
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- MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Meteorology, Cambridge, Massachusetts 02139.
Professor Henry G. Houghton, Department Head.
- (7435)
DYNAMIC METEOROLOGY AND OCEANOGRAPHY.
(b) National Science Foundation.
- (c) Prof. Jule G. Charney, and Prof. Norman A. Phillips.
- (d) Theoretical.
- (e) Study of the general circulation of the atmosphere and oceans: frontogenesis, tropical and extra-tropical cyclogenesis, formation of the intertropical convergence zone, planetary wave propagation, dynamics of the equatorial undercurrent, stability of atmospheric and oceanic motions, dynamic coupling of atmosphere and oceans.
- (h) "Dynamics of Disturbances of the Intertropical Convergence Zone," John R. Bates, Ph.D. thesis, M.I.T., 1969.
- "Large-Scale Response of the Ocean to Sea Ice Formation," Harold Solomon, Ph.D. thesis, M.I.T., 1969.
- "Three-Dimensional Nongeostrophic Disturbances in a Baroclinic Zonal Flow," J. Derome and C. L. Dolph, Geophys. Fluid Mech. (in press).
- "On the Non-Separable Baroclinic Parallel-Flow Instability Problem," M. McIntyre, J. Fluid Mech. (in press).
- "Diffusive Destabilization of the Baroclinic Circular Vortex," M. McIntyre, Geophys. Fluid Mech. (in press).
- "Role of Diffusive Overturning in Nonlinear Axisymmetric Convection in a Differentially Heated Rotating Annulus," M. McIntyre, Geophys. Fluid Mech. (in press).
- (7436)
OCEANOGRAPHIC DEEP CURRENT MEASUREMENT BY INERTIAL DEVICES.
(b) Office of Naval Research.
(c) Prof. D. P. Keily.
(d) Experimental.
- (e) Study of the application of inertial and acceleration devices to the location of submerged oceanographic sensors in water space over long and short time scales.
- (h) "Determination of the Hydrodynamic Shape for a Free-Fall Ocean Current Probe," David W. Kuperstein, ONR Report, Contract Nonr 1841(74) Dept. Meteor., M.I.T., 1966.
- "A Free-Fall Ocean Current Probe," Jerry H. Cook, S.M. Thesis, Dept. Meteor., M.I.T., 1967.
- (7437)
TURBULENT CONVECTION.
(b) Department of the Air Force.
(c) Prof. Erik L. Mollo-Christensen.
(d) Theoretical and experimental.
- (e) Investigation of turbulent convection between parallel plates of high Rayleigh numbers and Grashof numbers in air, with particular attention paid to the spatial structure of the turbulent field, and the effect of external disturbances upon the turbulence.
- (h) "Boundary Layer Oscillations Over a Resonant Surface," E. L. Mollo-Christensen and P. B. Rhines, Physics of Fluids 10, 5, 916-925, 1967.
- "The Toms Phenomenon: Turbulent Pipe Flow of Dilute Polymer Solutions," P. S. Virk, E. W. Merrill, H. S. Mickley, K. A. Smith and E. L. Mollo-Christensen, J. Fluid Mech., 30, 305, 1967.
- "Experimental and Theoretical Investigation of the Stability of Air Flow Over a Water Surface," A. K. Gupta, M. T. Landahl and E. L. Mollo-Christensen, J. Fluid Mech., 33, 673, 1968.
- "Thermal Convection Between Sloping Parallel Boundaries," John E. Hart, Sc.D. Thesis, Dept. Meteor., M.I.T., 1970.
- (7438)
AIR-SEA INTERACTION.
(b) National Science Foundation; Office of Naval Research.
(c) Prof. Erik L. Mollo-Christensen.
(d) Theoretical and experimental.
- (e) The measurement of wind profile and wind stress below one meter above the water surface. In addition the mechanism of wave generation by wind, air and water turbulence and vertical fluxes of momentum and heat are being investigated.
- (h) "A Field Investigation of Air Flow Immediately Above Ocean Surface Waves," R. Seesholtz, Ph.D. thesis, Dept. Meteor., M.I.T., 1968.
- "Observations of the Wind Field in the First Ten Meters of the Atmosphere Above the Ocean," Kenneth Ruggles, Ph.D. thesis, Dept. Meteor., M.I.T., 1969.
- "An Experimental Study of the Interactions Between Ekman Layers and an Annular Vortex," A. W. Green, Ph.D. thesis, Dept. Meteor., M.I.T., 1968.
- "Observation of Propagation Characteristics of a Wind-Driven Sea," O. Von Zwick, Ph.D. thesis, Dept. Meteorology, M.I.T., 1969.
- "An Experimental In Situ Densitometer," H. Kuenzler, Tech. Report, 1968.

"Vorticity and the Aerodynamics of the Modern Airplane," E. Mollo-Christensen, Tech. Report. 1969.

"Research on the Dynamics of the Small-Scale Processes of Air-Sea Interaction," E. Mollo-Christensen, Tech. Report, 1970.

"The Collection of Facts Needed for an Adequate Understanding of Air-Sea Interaction and Other Flux Processes," E. Mollo-Christensen, M.I.T. Tech. Report, 1970.

"Observations and Speculations on Mechanics of Wave Generation," E. Mollo-Christensen, M.I.T. Tech. Report, 1970.

(7439)

GEOPHYSICAL FLUID DYNAMICS.

(b) National Science Foundation.

(c) Prof. Robert C. Beardsley.

(d) Theoretical and experimental.

(e) Current areas of interest are the "spin-up" on a stratified fluid, laminar convection, internal waves, and laboratory and numerical models of the wind-driven ocean circulation.

(h) "A Theoretical and Experimental Study of the Slow Viscously Driven Motion of a Barotropic Fluid in a Rapidly Rotating Cylinder with Sloping Bottom," Robert C. Beardsley, Ph.D. thesis, Dept. Earth and Planetary Sci., M.I.T., 1968.

"A Laboratory Model of the Wind-Driven Ocean Circulation," Robert C. Beardsley, J. Fluid Mech., 38, 225, 1969.

(7440)

STEADY AND SLOWLY OSCILLATING OCEANIC MOTIONS.

(b) ONR-NSF-MIT.

(c) Prof. Peter B. Rhines.

(d) Theoretical.

(e) Study of the geophysical fluid dynamics of rotation, stratification and unsteadiness. Particular attention is focused on motions near the oceanic boundaries (shelf waves and up-welling forced by wind stress, meandering of currents); interaction of long (Rossby) waves with the mean flow; and formation of a layered structure in the ocean due to gravity-wave/current interactions.

(h) "Slow Oscillations in an Ocean of Varying Depth, Part I. Abrupt Topography," P. B. Rhines, J. Fluid Mech., 37, 161, 1969.

"Slow Oscillations in an Ocean of Varying Depth, Part II. Islands and Seamounts," P. B. Rhines, J. Fluid Mech., 37, 191, 1969.

"Wave Propagation in a Periodic Medium, With Application to the Ocean," P. B. Rhines, Rev. of Geophys. (in press), 1960.

"Edge-, Bottom- and Rossby-Waves in a Rotating Stratified Fluid, P. B. Rhines, J. Geophys. Fluid Dyn., 1, 2, 1970.

(7441)

OCEANIC PHYSICS.

(b) Henry M. Stommel, Prof.

(c) NSF-ONR.

(d) Theoretical and experimental.

(e) A study of large-scale ocean circulation.

(h) "Oceanographic Applications of Quartz Crystal Thermometry," Alexander E. Gilmour, Ph.D. thesis, Dept. Meteor., M.I.T., 1968.

"Observations of Short Period Internal Waves in Massachusetts Bay," David Halpern, Ph.D. thesis, Dept. Meteor., M.I.T., 1969.

"On the Theory of Coastal Upwelling," Ants Leetmaa Ph.D. thesis, Dept. Meteor., M.I.T., 1969.

"Circulation Produced by Applied Stress and Heating," Henry Stommel and Claes Rooth, Deep

Sea Research, 1968.

"Distribution of Stations and Properties at Standard Depths in the Kuroshio Area," Henry Stommel and Thomas Winterfield, Chapter 5 in a Treatise on the Kuroshio, Tokyo Un. Press, 1968.

"Hadaka's Onions," Henry Stommel and Robert Frazel, J. Oceanog. Soc. Japan, 1968.

"Regular Steps in the Main Thermocline Near Bermuda," Henry Stommel, and John Cooper, 1968 (in press).

"Atlas and Results of Cruises 28 and 29 of the Eltanin," Henry Stommel, Bruce Warren, E. D. Stroup and Joseph Reid, Jr., Scorpio Expedition Report, 1968.

"Note to Nation. On the Discovery of the Deep Western Boundary Current over the Tonga-Kermadec Trench," Henry Stommel, 1968.

"Observations of the Diurnal Thermocline," Henry Stommel, Kim Saunders, William Simmons and John Cooper, Deep Sea Research, 1969.

"The Initial Phase of Deep Water Formation in the North-west Mediterranean During MEDOC 1969 on the Basis of Observations Made by Atlantis II, January 25, 1969 to February 12, 1969," Henry Stommel and David Anati, Cashiers Oceanographique, 1970.

"Deep Wintertime Convection in the Western Mediterranean Sea," Henry Stommel, Wust Jubilee Volume, 1970.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Naval Architecture and Marine Engineering, Cambridge, Massachusetts 02139. Professor Martin A. Abkowitz, Director, Ship Model Towing Tank.

(6607)

MAINTAINING SHIP SPEED AT SEA-SHIP PERFORMANCE IN A SEAWAY.

(b) U. S. Maritime Administration.

(d) Experimental and theoretical; applied research, development; masters and doctor theses.

(e) The broad aspect of improving ship performance in rough seas is being studied by more specific investigations in the following areas: (1) improvement in model testing techniques for performance prediction and evaluation; (2) improvement and consolidation of theoretical methods for prediction of ship responses* in a seaway, including added resistance in a seaway; (3) development and application of techniques to predict maximum response in a given seaway; (4) development of consolidated, but extensive computer programs to facilitate the application of these developments into the design process; (5) model investigation of transom stern hulls in a seaway.

*Responses are displacements, velocities, accelerations, speed loss, structural loading, slamming, etc.

(h) "A Computerized Procedure for Prediction of Seakeeping Performance," Robert F. Beck, Rept. 69-2, Dept. of Naval Arch. and Marine Engrg., MIT, March 1969.

"An Analytical and Experimental Study for Prediction of Ship Impact Forces in a Seaway," Owen H. Oakley, Jr., Rept. No. 69-6, Dept. of Naval Arch. and Marine Engrg., MIT, Dec. 1969.

"Experimental Determination of Ship Response Extremes in a Seaway," Theodore Loukakis, Rept. No. 69-1, Dept. of Naval Arch. and Marine Engrg., MIT, Feb. 1970.

"Motion and Joint Loads of a Barge Train in Waves," I. T. Eleftheriou, Rept. No. 67-15,

(6609)

MAXIMUM MOTIONS AND BENDING MOMENT LOADINGS OF DESTROYERS IN SEVERE SEA STATES.

- (b) U.S. Navy, Naval Ship Res. and Dev. Ctr.
- (d) Experimental and theoretical; applied research and development.
- (e) To use and further develop the technique of generating, in the towing tank, long time samples of random irregular seas of any specified spectral distribution. The specific model testing program involves the determination of maximum responses, especially midship bending moment, of destroyer models, with and without large bow sonar domes, in several heavy sea states. Development of the technique involved (1) the building of a unique beach in the towing tank in order to kill wave reflections to allow long time samples and (2) the generation of purely random seas of given spectral content by means of a white noise generator.
- (h) "Extreme Wave Heights and Ship Responses in a Seaway," Theodore Loukakis, Rept. No. 70-5, Dept. of Naval Arch. and Marine Engrg., MIT, March 1970.
- "Experimental Modelling of Seaways," Theodore Loukakis and Owen Oakley, Jr., Rept. No. 70-6, Dept. of Naval Arch. and Marine Engrg., MIT, March 1970.

UNIVERSITY OF MASSACHUSETTS, School of Engineering,
Amherst, Massachusetts 01002. Dr. K. G. Picha, Dean.

(2561)

HYDROLOGY STUDIES IN MASSACHUSETTS.

- (b) Cooperative with the U.S. Geological Survey, the Mass. Water Resources Commission, and the Mass. Water Resources Research Center.
- (c) Assoc. Prof. George R. Higgins.
- (d) Experimental; field and laboratory; for hydrologic information to better assess the water resources potential of the Commonwealth.
- (e) Flow duration curves and recurrence interval curves were prepared for nearly all the gaged streams in Massachusetts through the water year 1962. Mass curves for storage-yield relationships have been extended through 1965. Present emphasis is concerned with evaporation studies to determine the effect of evaporation on reservoir yield in New England.
- (h) A 250-page "Preliminary Report" was submitted to the Massachusetts Water Resources Commission in 1964 and an updated "Interim Report" was submitted to the Massachusetts Water Resources Center in 1967. Copies are available upon request.

(5371)

A PHOTOMICROSCOPIC INVESTIGATION OF NON-NEWTONIAN FLOWS AT LOW REYNOLDS NUMBERS.

- (b) Naval Ship Research and Development Center.
- (c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg.
- (d) Experimental; basic research.
- (e) Laminar velocity profiles have been determined from photomicrographs of the motion of polystyrene latex spheres 0.557 microns in diameter dispersed in distilled water and three different aqueous solutions of non-Newtonian additives flowing in a lucite channel of cross-section 13×1.5 mm at a channel Reynolds number of 0.92.
- (g) Velocity profile for distilled water agrees within 2% with the theoretical parabolic distribution for laminar flow between parallel flat plates.

Profiles for the additives at both concentrations of 0.125% and 0.25% were indistinguishable from that of distilled water except near the boundaries, from 20-50 microns, where the velocity was measurably higher. Experiments are being repeated for turbulent flow in a 0.25-inch circular tube using high speed cinematographic photography.

- (h) "Measurement of Laminar Velocity Profiles with Non-Newtonian Additives," in Fluid Mech. Lab. Tech Rept. No. 1.
- "An Investigation of Velocity Profiles in the Laminar Sublayer with Non-Newtonian Additives using High Speed Photomicroscopy," C. E. Carver, Jr. and R. H. Nadolink, UMASS Report No. ERI-69-3, May 1969.

(5373)

EFFICIENCY OF SPRAY AERATION.

- (b) National Institutes of Health, U.S. Public Health Service.
- (c) Dr. Charles E. Carver, Jr.
- (d) Experimental; basic research.
- (e) Overall oxygen transfer coefficients have been measured for deaerated water droplets falling through the atmosphere as a function of drop size and drop distance. The experiments are repeated with a synthetic detergent added to the water. Transfer coefficients are also measured from fully aerated water droplets falling through a pure nitrogen atmosphere as a function of drop size and drop distance and these experiments are repeated with a synthetic detergent added.
- (f) Completed.
- (h) "Oxygen Transfer from Falling Water Droplets," C. E. Carver, Jr., J. San. Engrg. Div., Am. Soc. Civil Engrs., pp. 239-251, April 1969.

(6666)

FEASIBILITY STUDY ON THE USE OF A PNEUMATIC BREAK-WATER FOR THE SURFACE LAUNCHING OF A MANNED SUBMERSIBLE.

- (b) Dept. of Defense, Project THEMIS.
- (c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg.
- (d) Experimental.
- (e) Experiments will be conducted in a wave channel in which wind waves will be generated in order to estimate power requirements for reducing wave amplitudes using a pneumatic breakwater. Ultimate aim is to produce a tranquil zone in the vicinity of a mother ship for the safe launching of a small manned submersible. Wind wave flume has been completed and calibrated and appropriate instrumentation for obtaining wave spectra has been obtained. Experiments using a simple perforated pipe to serve as a pneumatic breakwater are about to proceed.

(6677)

DEVELOPMENT OF A MOMENT METHOD TO SOLVE THE THREE-DIMENSIONAL BOUNDARY LAYER EQUATIONS.

- (b) National Aeronautics and Space Administration.
- (c) Prof. J. Fillo, Dept. of Mechanical and Aerospace Engrg.
- (d) Theoretical.
- (e) Utilization of the moment method to solve three-dimensional boundary layer equations.

(6681)

WIND TUNNEL TESTING OF MARINE VEHICLE COMPONENTS.

- (b) Dept. of Defense, Project THEMIS.
- (c) Dr. D. E. Cromack, Dept. of Mechanical and Aerospace Engrg.
- (d) Basic and applied; theoretical and experimental;

- Ph.D. Thesis.
- (e) Pressure field associated with a ducted propeller is being investigated analytically and in an open jet wind tunnel.
 - (g) "Ducted Propellers -- A Review and Description of Current Investigation," R. J. Weetman and D. E. Cromack, Report No. THEMIS-UM-70-1.
- (6682)
A STUDY OF AIRBORNE TOWED VEHICLE DYNAMICS.
- (b) U.S. Army Research Office.
 - (c) Drs. C. R. Poli or D. E. Cromack, Dept. of Mechanical and Aerospace Engrg.
 - (d) Basic and applied; theoretical and experimental; Masters and Ph.D.
 - (e) Stability of towed bodies including cable effects.
- (7816)
THERMAL RESPONSE OF RESERVOIRS TO HYDROLOGIC INFLUENCES.
- (b) Massachusetts Water Resources Research Center and Office of Water Resources Research.
 - (c) Dr. Joseph M. Colonell, Civil Engrg. Dept.
 - (d) Theoretical with verification by field investigation.
 - (e) Under investigation are existing techniques for numerical simulation of the thermal response of reservoirs to hydrologic influences. Computer predictions of the thermal structure of nearby Quabbin Reservoir are being tested by appropriate field measurements.
- (7817)
SIMULATION TECHNIQUES FOR DYNAMIC MODELING OF OCEAN ENGINEERING STRUCTURES.
- (b) Department of Defense, Project THEMIS.
 - (c) Dr. Joseph M. Colonell, Civil Engrg. Dept.
 - (d) Experimental; applied research.
 - (e) Models of simple ocean engineering structures will be tested for their response to wind-generated waves in a laboratory sea wave facility designed by the author in connection with another project (6666). The objective is to examine basic similitude relationships for fixed and floating structures in a random seaway.
- (7818)
COMPUTER TECHNIQUES FOR VISUALIZATION OF TWO-DIMENSIONAL FLUID FLOW PHENOMENA.
- (c) Dr. Joseph M. Colonell, Civil Engrg. Dept.
 - (d) Theoretical.
 - (e) Digital computer techniques are being developed for visualization of two-dimensional flow fields. The objective is to provide a computerized visual aid for instruction in basic hydrodynamics.
- (7819)
EFFECTS OF NONUNIFORM WAVE ENERGY DISTRIBUTION IN THE LITTORAL ZONE.
- (c) Dr. Joseph M. Colonell, Civil Engrg. Dept.
 - (d) Theoretical with verification by field investigation.
 - (e) Under investigation is the hypothesis that wave refraction due to uneven offshore bathymetry can produce zones of wave energy concentration at regularly spaced intervals along the shore.
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- MECHANICAL TECHNOLOGY INCORPORATED, 968 Albany-Shaker Road, Latham, New York 12110. Dr. C. H. T. Pan, Director of Research.
- (7450)
VORTEX INSTABILITY IN ECCENTRIC ANNULI.
- (b) NASA Lewis Research.
 - (c) C. H. T. Pan, Mech. Tech. Inc., and J. H. Vohr, Fluid, Chemical and Thermal Processes Div., Rensselaer Polytechnic Inst., Troy, New York 12181.
 - (d) Basic research; experimental.
 - (e) Flow in an eccentric annulus with the inner cylinder rotating was studied by torque measurement and visualization for a wide range of eccentricity-Reynolds number combination. Two values of gap-to-radius ratio were obtained, 0.1 and 0.01, by changing the bore of the outer cylinder.
 - (f) Completed.
 - (g) Eccentricity effect on transition point was found to be in qualitative agreement with thin film stability calculation. However, there was definite evidence in the presence of inertial effects, which were more pronounced at larger gap-to-radius ratios. Progression of flow regimes from laminar to vortices, then to wavy vortices, then to "random fluctuations" without vortices developed with speed increase. At large eccentricities, because of large circumferential variation of Reynolds number, two or more flow regimes could exist simultaneously. Non-inertial aspect of the measured profile followed closely second order thin film calculation. Pressure and torque data developed from transition to "fully turbulent" behavior gradually.
 - (h) "Experimental Study of Superlaminar Flow Between Nonconcentric Rotating Cylinders," J. H. Vohr, NASA CR-749 (1967); also ASME Trans., J. Lub. Tech., Vol. 90, Series F, 285-296 (1968). A 16 mm motion picture film was made of the flow patterns described in this study. Requests to borrow a copy of this film (Visual Brief #28, Journal Bearings in Laminar and Turbulent Regimes) should be directed to Joseph P. Joyce, Mail Stop 500-201, NASA Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio 44135.
- (7451)
WALL TURBULENCE.
- (c) Thomas J. Black, Technical Director, Keene Corporation Development Center, Isaac Newton Square, W., Reston, Virginia 22070, and C. H. T. Pan, Mech. Tech. Inc.
 - (d) Theory; applied research.
 - (e) The turbulent boundary layer was analyzed with respect to its fluctuating and intermittent character by postulating the mechanisms of temporal sublayer instability, periodic eruption of the sublayer discharging horseshoe vortices, vortex induction controlling the velocity distribution in the fully turbulent zone, vortex shear stress, and development of the laminar sublayer. This model was further extended to consider the mechanism of drag reduction with macromolecular additives.
 - (f) Completed.
 - (g) Preliminary computations yielded velocity profile consistent with the well established universal law. The role of macromolecules is mainly the stabilization of the laminar sublayer, thereby its thickness is increased with corresponding reduction in wall friction. It was further deduced that the longitudinal velocity fluctuations would also be increased.
 - "A New Model of the Shear Stress Mechanism in Wall Turbulence," T. J. Black, AIAA Paper No. 68-42.
 - "Viscous Drag Reduction Examined in the Light of a New Model of Wall Turbulence," T. J. Black, Proc. Symp. on Viscous Drag Reduction, ed. by C. S. Wells, Plenum Press, 383-407 (1969).

(7452)

DYNAMICS OF NON-EQUILIBRIUM FORCED CONVECTIVE BOILING.

- (b) NASA Headquarters.
- (c) J. H. Vohr, Fluid, Chemical and Thermal Processes Div., Rensselaer Polytechnic Inst., Troy, New York 12181, and C. H. T. Pan, Mech. Tech. Inc.
- (d) Survey; analytical; applied research.
- (e) Experimental data on liquid metal superheat for boiling incipience was reviewed. Non-equilibrium vaporization processes in forced convection passages was studied according to first principles.
- (f) Completed; two additional reports are being reviewed by sponsor.
- (g) Data on boiling incipience superheat for liquid metals showed the significance of deactivation history causing flooding of larger surface nucleation sites. A second phenomenon was the thickness of superheat sublayers to supply heat to the growing bubble attached to a wall cavity. Correlation formulae for various fluids were established. In reports under review, non-equilibrium vaporization rates were derived for various flow regimes.
- (h) "A Review of Criteria for Predicting Incipient Nucleation in Liquid Metals and Ordinary Fluids," J. H. Vohr and T. Chiang, Tech. Rept. MTI-69TR45, prepared for NASA Headquarters, Washington, D.C., Contract NASw-1705. For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

(7453)

TRANSITION AND TURBULENCE OF THIN FILM FLOWS WITH TEMPERATURE EFFECTS.

- (b) NASA Lewis Research Center.
- (d) Analytical; applied research.
- (e) Computation of thin film shear flow velocity and temperature profiles with law of wall modified to allow for temperature dependence of viscosity.

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Aerospace Engineering, Ann Arbor, Michigan 48104. Professor R. M. Howe, Department Chairman.

(7442)

AN INVESTIGATION OF WALL PRESSURE FLUCTUATIONS AND STRUCTURE OF A TURBULENT BOUNDARY LAYER.

- (b) Office of Naval Research, Fluid Dynamics Branch.
- (c) Prof. William W. Willmarth.
- (d) Experimental, basic research, doctoral thesis.
- (e) Fluctuating velocity and pressure measurements in and beneath turbulent boundary layers. Purpose is basic research on turbulence.
- (g) We have new measurements of wall pressures beneath boundary layers with transverse curvature showing effect of transverse curvature on turbulent structure and wall pressures.
- (h) "Wall-Pressure Fluctuations Beneath Turbulent Boundary Layers on a Flat Plate and a Cylinder," W. W. Willmarth and C. S. Yang, J. Fluid Mech., Vol. 41, Part 1, pp. 47-80, March 1970.

(7443)

UNSTEADY AERODYNAMIC FLOWS.

- (b) Army Research Office, Durham.
- (c) Prof. William W. Willmarth.
- (d) Experimental, basic research.
- (e) Fluctuating force measurements and simultaneous flow visualization. Work done in a large (air) wind tunnel and a small 2' x 2' x 32' towing channel (filled with various viscosity liquids).

Channel fitted with air bearing supported towing carriage. Purpose is basic research and understanding of unsteady flow at low and high Reynolds number.

- (g) "Hydrogen Bubble Flow Visualization at Low Reynolds Numbers," F. W. Roos and W. W. Willmarth, J. AIAA, 7, 8, 1969.
"Aerodynamic Lift and Moment Fluctuations of a Sphere," W. W. Willmarth and R. L. Enlow, J. Fluid Mech., Vol. 36, Part 3, p. 417-432, 1969.
"Some Experimental Results on Sphere and Disk Drag," F. W. Roos and W. W. Willmarth, submitted to AIAA Journal.

UNIVERSITY OF MICHIGAN, Department of Chemical and Metallurgical Engineering, Sonochemical Engineering Laboratory, Division of Chemical Engineering, Ann Arbor, Michigan 48104. Dr. H. Scott Fogler, Assistant Professor.

(7444)

CAVITATION IN VISCOELASTIC FLUIDS.

- (d) Theoretical and experimental.
- (e) In the experimental phase of this study we are photographing collapsing cavities produced by an electric spark in a viscoelastic fluid. A concurrent program is underway to theoretically model the collapse of these cavities in viscoelastic fluids.
- (g) Preliminary results indicate that liquid elasticity can significantly retard the collapse of a spherical void, and in some cases produce prolonged oscillatory motion rather than catastrophic collapse.

(7445)

LIQUID PHASE MASS TRANSPORT ACCELERATED BY ACOUSTIC STREAMING.

- (d) Theoretical and experimental.
- (e) This is an experimental and theoretical study of gas absorption which is enhanced by acoustic streaming. Ultrasonic waves are imparted to thin liquid films in which one film boundary is a metal plate and the other boundary is the free interface at which the absorbing gas enters the film.
- (g) The experimental acoustic streaming speeds in these thin films appear to be much greater than any speeds reported either theoretically or experimentally. It is believed that this microstreaming phenomenon should greatly enhance mass transfer rates into thin liquid films.

(7446)

CHEMICAL REACTIONS IN CAVITATION BUBBLES.

- (d) Theoretical and experimental.
- (e) This work concerns a fundamental study on gas phase reactions occurring during the collapse phase of an ultrasonically induced cavitation bubble in a large body of liquid. The initial phases of this work are centered around much studied CCl₄-water reactions. It is believed that once the mechanism for this reaction during collapse is understood, we will be able to predict what other reactions may be accelerated ultrasonically.

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Civil Engineering, Ann Arbor, Michigan 48104. Dr. E. F. Brater, Professor of Hydraulic Engineering.

- (4858)
WATER HAMMER: RESONANCE IN TRIPLEX PUMP SUCTION AND DISCHARGE LINES.
(b) National Science Foundation; Union Pump Co.
(c) Prof. V. L. Streeter.
(d) Theoretical and experimental; basic research.
(e) Theoretical determination of resonance-free suction lines and experimental study of actual transients.
(f) Completed.
(g) Excellent agreement obtained with experiment using linearized impedance methods and the non-linear characteristics method.
- (h) "Hydraulic Transients Caused by Reciprocating Pumps," V. L. Streeter and E. B. Wylie, Paper No. 66-WA/FE-29, ASME Winter Ann. Mtg., New York, Nov. 27-Dec. 1, 1966.
- (4859)
PULSATILE FLOW THROUGH ARTERIES.
(b) National Institutes of Health.
(c) Prof. V. L. Streeter.
(d) Theoretical and experimental; basic research.
(e) Computer simulation of portions of the arterial tree; experimental studies of energy dissipation in pulsatile flow through distensible tubes.
(f) Completed.
(h) "Unsteady Flows in Lines with Distributed Leakage," David C. Wiggert, J. Hyd. Div., ASCE, Vol. 94, No. HY 1, Jan. 1968, pp. 143-162.
"Frequency Dependent Friction in Transient Pipe Flow," W. Zielke, Paper No. 67-WA/FE-15, ASME Winter Ann. Mtg., Pittsburgh, Pa., Nov. 12-17, 1967.
- (4862)
WATER HAMMER, LIQUID COLUMN SEPARATION.
(b) National Science Foundation.
(c) Prof. V. L. Streeter.
(d) Theoretical and experimental; basic research for doctoral thesis.
(e) Study of wall shear under cavitating conditions.
(f) Completed.
(h) "Column Separation Accompanying Liquid Transients in Pipes," R. A. Baltzer, Paper No. 67-WA/FE-16, ASME Winter Ann. Mtg., Pittsburgh, Pa., Nov. 12-17, 1967.
- (4946)
RESONANCE IN PIPE LINES.
(b) National Science Foundation.
(c) Prof. E. B. Wylie.
(d) Theoretical and experimental.
(e) Study of resonance in complex systems.
(f) Completed.
(h) "Schwingungen in Druckrohrleitungen Anwendung der Impedanz-Methode unter Berücksichtigung des Reibungsflusses," E. B. Wylie and W. Zielke, Die Wasserwirtschaft, 57 Jahrgang, Heft 2, pp. 91-96, 1967.
- (5558)
FLOOD PREDICTION.
(b) Michigan State Highway Dept.; and Federal Highway Administration.
(d) Analysis of field data, basic research.
(e) Rainfall and runoff data from small watersheds in southwestern Michigan are being analyzed to determine infiltration capacities and flood hydrograph shapes for the purpose of predicting the frequency of floods on watersheds in various stages of urbanization.
(g) Methods are being developed for relating changes in hydrograph shape and amount of impermeable area to population density.
- (h) "Steps Toward a Better Understanding of Urban Runoff Processes," E. F. Brater, Water Resources Res., Vol. 4, No. 2, April 1968, p. 335.
"Effects of Urbanization on Peak Flows," E. F. Brater and S. Sangal, The Effects of Watershed Changes on Streamflow, Center for Research on Water Resources, Univ. of Texas, 1968.
- (5916)
RAINFALL-RUNOFF RELATIONS ON URBAN AND RURAL AREAS.
(b) Federal Water Pollution Control Admin.
(d) Analysis of field data, basic research.
(e) Rainfall and runoff data from small watersheds in various stages of urbanization are being studied to determine the effect of such factors as size of basin, the amount of impermeable areas, shape of basin and the nature of the drainage network in storm runoff.
(g) Methods are being developed for relating changes in hydrograph shape and amount of impermeable area to population density. A mathematical model has been used to extend the range of the parameters being studied.
- (h) "Steps Toward a Better Understanding of Urban Runoff Processes," E. F. Brater, Water Resources Res., Vol. 4, No. 2, April 1968, p. 335.
"Effects of Urbanization on Peak Flows," E. F. Brater and S. Sangal, The Effects of Watershed Changes on Streamflow, Center for Research on Water Resources, Univ. of Texas, 1968.
- (5917)
VALVE STROKING TO CONTROL WATERHAMMER.
(b) National Science Foundation.
(c) Prof. V. L. Streeter.
(d) Theoretical and experimental.
(e) Development of theoretical equations for motion of a valve so that the transient ceases the instant the valve motion ceases; confirmation on 4,000 ft. line with servo-operated valve.
(f) Suspended.
(h) "Valve Stoking for Complex Piping Systems," V. L. Streeter, J. Hyd. Div., ASCE, Paper 5238, HY3, May 1967, pp. 81-98.
- (6423)
UNSTEADY OPEN CHANNEL FLOW.
(b) National Science Foundation.
(c) Professor E. B. Wylie.
(d) Theoretical.
(e) Study of the control of transient conditions in open channels.
(h) "Control of Transient Free-Surface Flow," E. B. Wylie, ASCE, J. Hydr. Div., Vol. 95, No. HYL, Jan. 1969.
- (6424)
WAVE FORCES ON SUBMERGED STRUCTURES.
(b) National Science Foundation.
(d) Experimental; basic research and application to engineering design.
(e) Study of forces on submerged pipe lines.
(g) Testing program in progress - data analysis under way.
- (6425)
TRANSIENTS IN GAS DISTRIBUTION SYSTEMS.
(b) National Science Foundation.
(c) Prof. V. L. Streeter.
(d) Theoretical and experimental (field); basic research, for doctor's degree.
(e) Application of characteristics method for control of gas distribution systems.
(h) "Natural Gas Pipeline Transients," V. L. Streeter and E. B. Wylie, SPE of AIME, Paper No. SPE 2555,

- (6426)
SUCTION LINE DYNAMICS SATURN V ROCKET.
(b) NASA.
(c) Prof. V. L. Streeter.
(d) Experimental and theoretical.
(e) Study of possible longitudinal oscillation of the structure caused by cavitations in the fuel pump suction lines.
(f) Completed.
(g) Explanation of coupling cycle for longitudinal (pogo stick) vibrations.
(h) "Forced and Self-Excited Oscillations in Propellant Lines," W. Zielke, E. B. Wylie and R. B. Keller, ASME Trans., J. Basic Engrg., Vol. 91, Series D, No. 4, Dec. 1969, pp. 671-677.

- (7454)
DEVELOPING HARBOR FOR PUMPED STORAGE PLANT.
(b) Ebasco Corporation.
(d) Experimental.
(e) The harbor plans were developed to protect the pumping-generating structure from Lake Michigan storms and to minimize currents during both modes of operation for a plant having a peak discharge of over 70,000 cfs and a head of more than 300 feet.
(f) Testing completed - report being prepared.

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Engineering Mechanics, Ann Arbor, Michigan 48104. Dr. J. W. Daily, Department Chairman.

- (6170)
STABILITY AND SECONDARY FLOWS IN STRATIFIED FLUIDS.
(b) Army Research Office.
(c) Prof. C. S. Yih.
(d) Theoretical and experimental research.
(e) Investigation of stability of stratified flows down inclined planes; wind generated waves; and convective instability in flowing fluids.
(g) Theoretical solutions have been obtained to a number of problems which are discussed in the publication below.
(h) "A Class of Solutions for Steady Stratified Flows," J. Fluid Mech., Vol. 36, pp. 75-85, 1969.

- (6171)
DRAG REDUCTION.
(b) Office of Naval Research.
(c) Prof. W. P. Graebel.
(d) Theoretical and experimental basic research.
(e) An investigation of the effect of non-Newtonian fluid properties on drag reduction.
(g) Theoretical and experimental solutions have been obtained to a number of problems which are discussed in the publication below.
(h) "On Determination of the Characteristic Equations for the Stability of Parallel Flow," J. Fluid Mech., Vol. 24, No. 3, pp. 497-508, 1966. Technical report (ORA), "Laser Anemometer Measurements of Turbulence in Non-Newtonian Pipe Flow," with J. S. Chung.

- (6172)
SUPERCritical CIRCULAR COUETTE FLOW.
(c) Prof. W. R. Debler.
(d) Experimental research.
(e) The investigation of speed-torque relationship immediately after Taylor instability occurs.
(g) The slope of the speed-torque curve has been obtained for various cylinder diameter ratios

ranging from 0.50 to 0.95. The outer cylinder was constrained by a torsion wire and air bearing.

- (h) "Torque and Flow Patterns in Supercritical Circular Couette Flow," Proc. 12th Intl. Cong. Applied Mech., Stanford Univ., Aug. 1968.
(6173)
INTERNAL WAVES AND WAKES IN A STRATIFIED FLOW.
(b) Office of Naval Research.
(c) Prof. W. R. Debler.
(d) Experimental research.
(e) The study of the role of stratification on the development of two- and three-dimensional wakes; the generation of internal waves by the body and its wake in a stratified fluid.

- (7447)
STABILITY OF UNSTEADY FLOWS.
(b) National Science Foundation.
(c) Prof. C. S. Yih.
(d) Theoretical and experimental basic research.
(e) Stability of time independent flows.
(g) Theoretical solutions have been obtained to a number of problems which are discussed in the publication below.
(h) "Instability of Unsteady Flows or Configurations. Part I. Instability of a Horizontal Liquid Layer on an Oscillating Plane," J. Fluid Mech., Vol. 31, pp. 737-751, 1968. "Stability of a Horizontal Fluid Interface in a Periodic Vertical Electric Field," Physics of Fluids, Vol. 11, pp. 1447-1449.

- (7448)
TURBULENCE IN A STRATIFIED FLOW.
(b) National Science Foundation.
(c) Prof. W. R. Debler.
(d) Experimental research.
(e) An investigation into the decay of turbulence which is created in a stratified flow.
(g) Data is being collected on grid generated turbulence.

UNIVERSITY OF MICHIGAN, Department of Mechanical Engineering, Ann Arbor, Michigan 48104. John A. Clark, Department Chairman.

- (6144)
ASYMMETRIC BUBBLE COLLAPSE.
(b) National Science Foundation; Army Research Office - Durham.
(c) Prof. F. G. Hammitt, Cavitation and Multiphase Flow Laboratory.
(d) Theoretical and experimental; basic research for doctoral thesis.
(e) Study of the asymmetric collapse of vapor (and gas) bubbles in fluid streams.

- (6145)
CAVITATION STUDIES.
(b) Worthington Corp.
(c) Prof. F. G. Hammitt; see (6144) above.
(d) Experimental, applied research.
(e) Determination of the relative resistances of metals and alloys to cavitation erosion under different conditions of temperature and pressure.
(f) Completed.

- (6146)
CAVITATION TESTING.
(b) Various industrial concerns.
(c) Prof. F. G. Hammitt; see (6144) above.
(d) Experimental operation.

- (e) Determination of the relative resistances of metals and alloys to cavitation erosion.

(6147) BUBBLE NUCLEATION, GROWTH AND COLLAPSE PHENOMENA.

- (b) National Science Foundation.
- (c) Prof. F. G. Hammitt; see (6144) above.
- (d) Experimental and theoretical; basic research for thesis.
- (e) Study of the details of the growth and collapse of vapor and gas bubbles in liquids with particular reference to the problem of sodium superheat.

(7475) DROPLET IMPINGEMENT.

- (b) Naval Air Development Command.
- (c) Prof. F. G. Hammitt; see (6144) above.
- (d) Experimental and theoretical; basic research and development.
- (e) Study of the details of supersonic droplet impingement on various materials and of relative resistances of materials to droplet erosion.

(7476) INVESTIGATION AND STUDY OF TRANSIENT HEAT TRANSFER.

- (b) NASA.
- (c) Prof. Herman Merte, Jr.
- (d) Experimental and theoretical; basic and applied research; Ph.D. thesis.
- (e) To study incipient boiling under low gravity, and the rate of pressure rise of a two-phase system in a closed container under the action of an imposed heat flux.
- (h) "Incipient and Nucleate Boiling of Liquid Hydrogen," K. J. Coeling and H. Merte, Jr., Trans. ASME, J. Engng. for Ind., 91B, No. 2, pp. 513, May 1969.
- "Transient Pressure Rise of a Liquid-Vapor System in a Closed Container Under Variable Gravity," H. Merte, Jr., J. A. Clark, E. R. Lady, C. C. Suh, presented at Fourth Intl. Heat Transfer Conf., Versailles/Paris, Aug. 31 - Sept. 5, 1970.

(7477) STUDY OF BOILING IN AN ACCELERATING SYSTEM.

- (b) National Science Foundation.
- (c) Prof. Herman Merte, Jr.
- (d) Experimental; basic - Ph.D. thesis.
- (e) To study influence of increasing body forces on nucleate pool boiling.
- (h) "A Photographic Study of Boiling in an Accelerating System," (with W. A. Beckman), Trans. ASME, J. Heat Transfer, Vol. 87, Ser. C, No. 3, Aug. 1965.
- "Influence of Acceleration on Subcooled Nucleate Pool Boiling," R. L. Judd and H. Merte, Jr., presented at Fourth Intl. Heat Transfer Conf., Versailles/Paris, Aug. 31 - Sept. 5, 1970.

(7478) DEVELOPMENT OF MATHEMATICAL MODEL FOR A DRUM-TYPE STEAM GENERATING PLANT.

- (b) The Detroit Edison Company.
- (c) Wen-Jei Yang, Heat Transfer Lab.
- (d) Theoretical, applied, for technical publications.
- (e) Simulation of dynamic characteristics of two-phase flows in a drum-type steam generating plant.

(7479) PLASTIC PROCESSING CONTROLS AND SENSORS.

- (b) Borg-Warner Corporation.
- (c) Wen-Jei Yang; see (7478) above).
- (d) Theoretical; experimental; applied; doctoral theses.
- (e) Simulation of dynamic characteristics of two-phase

flows in plastic processing machines, including controls.

- (g) "Dynamic Response of Viscoelastic Fluid Lines," presented at the 5th Southeastern Conf. of Appl. Mech., Rayleigh, N. C., April 1970.
- "Fluid Transient and Heat Flows in Screw Viscosity Pumps, Part I," presented at Fluids Eng., Heat Transfer and Lubrication Conf., Detroit, Mich., May 1970 and subsequent publication in Trans. ASME.

(7480) DYNAMICS OF GAS BUBBLES IN EXTRACORPOREALLY OXYGENATED BLOOD.

- (b) National Institutes of Health.
- (c) Wen-Jei Yang; see (7478) above).
- (d) Experimental; theoretical; applied; doctoral theses.
- (e) Dynamic behavior of gas bubbles in extracorporeally oxygenated blood. Measurements of mass diffusivity and mass transfer coefficient of gases in bloods.
- (g) "Experimental Study of Air Bubbles in a Simulated Cardio-Pulmonary Bypass System with Flow Constriction," presented at 1970 Spring Meeting on Experimental Biomechanics, SESA, Huntsville, May 1970.
- "Measurements of Mass Diffusivity of Gases in Plasma and Reaction Velocity Constant in Bloods," presented at 1970 Spring Meeting on Experimental Biomechanics, SESA, Huntsville, May 1970.

(7481) CONDENSATION AND EVAPORATION OF WATER AND LIQUID METAL VAPORS.

- (b) U.S. Atomic Energy Commission.
- (c) George S. Springer, Fluid Dynamics Laboratory.
- (d) Experimental, theoretically applied; doctoral theses.
- (e) Theoretical and experimental investigations of heat and mass transfer during filmwise condensation of water and liquid metal vapors. Experimental evaluation of condensation and evaporation coefficients.
- (g) Analyses of heat and mass transfer through the vapor is completed.
- (h) "Kinetic Theory Description of Liquid Vapor Phase Change," A. J. Patton and G. S. Springer, in Rarefied Gas Dynamics, Academic Press, Vol. II, 1969, pp. 1497-1501.
- "Condensation on or Evaporation from Droplets by a Moment Method," R. E. Sampson and G. S. Springer, J. Fluid Mech., Vol. 36, Part 3, May 1969, pp. 577-584.
- "Vapor Phase Resistance in Filmwise Condensation," R. Barry and G. S. Springer, ASME Paper No. 69-WA/HT-26 (1969).

UNIVERSITY OF MICHIGAN, College of Engineering, Department of Meteorology and Oceanography, Ann Arbor, Michigan 48104. Edward S. Epstein, Acting Department Chairman.

(7482) SEA SPRAY AND WHITECAPPING.

- (b) Office of Naval Research.
- (c) Dr. Edward C. Monahan.
- (d) Experimental with field investigations; basic research.
- (e) It is the purpose of this study to investigate how fractional whitecap coverage (and sea spray production) varies with wind speed, atmospheric stability, water temperature and salinity, and

- fetch. Photographic observations are made from research vessels and platforms, and from "ships of opportunity."
- (f) Great Lakes study completed, oceanic study and laboratory simulations nearing completion.
 - (g) Distinctions between fresh and salt water whitecaps determined. Effects of atmospheric thermal stability and fetch now apparent.
 - (h) "Fresh Water Whitecaps," J. Atmos. Sci., 26, No. 5, Part 2, Sept. 1969, pp. 1026-1029.
"Laboratory Comparisons of Fresh-Water and Salt-Water Whitecaps," J. Geophysical Res. 75, No. 28, Dec. 20, 1969, pp. 6961-6966, (with Carl R. Zietlow, Northern Michigan Univ., Marquette, Mich. 49855).
- (7483)
AN INVESTIGATION OF THE STRUCTURE OF TURBULENCE AND OF THE TURBULENT FLUXES OF MOMENTUM AND HEAT OVER WATER WAVES.
- (b) Office of Naval Research.
 - (c) Prof. Donald J. Portman.
 - (d) Field investigation of some basic questions, part of which is for a doctoral thesis.
 - (e) Hot-wire and hot-film anemometers, fast response resistance wire thermometers and staff wave gages were used to measure simultaneously u' , v' , w' , T' (at two heights, 1 to 8 meters above waves) and wave heights in both Lake Michigan and the Atlantic Ocean (Project BOMEX). Influences of waves on the air flow and the fluxes of momentum and sensible heat over them is determined through spectral and cross spectral analysis.
 - (f) Data processing, analysis and interpretation.
 - (g) Initial results reflect features of the Miles mechanism with enhanced momentum flux at dominant wave frequency. Wave influence in the form of organized air motion is evident up to 6 meters above mean water level. Streamlines of the air motion at the dominant wave frequency show maxima in horizontal velocity over wave nodes, a phase shift with height, distortion and vertical translation, and are compatible with a general pressure greatest over troughs and least over crests.
 - (h) No publications. Progress reports out of print.
- (7484)
GRAVITY WAVES.
- (c) Dr. Stanley J. Jacobs.
 - (d) Theoretical work on the propagation of gravity waves; basic research.
 - (e) The work has been devoted to nonlinear interactions in gravity waves. This has included a theoretical study of the undular bore and a similar study of interactions between surface gravity waves and internal waves.
 - (f) Work completed.
 - (h) "On the Undular Bore," submitted for publication in J. Fluid Mech., Univ. of Mich. Rept. 07344-4-F. "Nonlinear Generation of Inertial Motions," Univ. of Mich. Rept., manuscript in preparation.
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- UNIVERSITY OF MICHIGAN, College of Engineering, Department of Naval Architecture and Marine Engineering, Ship Hydrodynamics Laboratory, Ann Arbor, Michigan 48104. Finn C. Michelsen, Laboratory Director.
- (6684)
EFFECTIVE AND SHAFT HORSEPOWER FOR HIGH SPEED TRANSON SHIPS.
- (d) Maritime Administration, U.S. Dept. of Commerce.
 - (d) Experimental; applied research; design.
- (e) Up to 9 different systematically related transoms are being designed and tested for resistance and propulsion characteristics through a broad speed range and under several different loading conditions each.
 - (g) Results will be available in early 1970.
 - (h) Final report to be prepared.
- (7485)
WAVE RESISTANCE OF AN AIR CUSION VEHICLE.
- (b) Office of Naval Research.
 - (c) Dr. Som D. Sharma.
 - (d) Theoretical; applied research.
 - (e) A theoretical study of the wave resistance of an air-cushion vehicle (ACV) in accelerated motion over shallow water with a view to determining the propulsive power required to overcome the resistance hump at critical depth Froude number.
 - (g) The power required to pass the critical speed in steadily accelerated motion is substantially less than would be expected from a simple quasi-steady approach.
 - (h) Final report will be available in January 1971.
- (7486)
HULL PROPELLER INTERACTION.
- (b) Naval Ship Research and Development Center.
 - (c) Dr. Som D. Sharma.
 - (d) Theoretical and experimental; applied research.
 - (e) The aim is to clarify by analysis, experiment and computation the role of wavemaking at the free surface in the phenomenon of hydrodynamic hull propeller interaction.
 - (g) Wavemaking can significantly affect the wake distribution in way of the propeller. The effect on thrust deduction is less important.
 - (h) Report will be available in November 1970.
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- UNIVERSITY OF MICHIGAN, Division of Engineering, Thermal Engineering Laboratory, Dearborn Campus, Dearborn, Michigan 48128. Professor Tsung Y. Na, Laboratory Director.
- (7487)
OPTIMUM DESIGN OF JET PUMP SYSTEMS AND ITS CAVITATION CHARACTERISTICS.
- (b) Experimental data used in this project were taken by A. G. Hansen (President of Georgia Institute of Technology) in 1962 at the Deming Division of the Crane Company.
 - (d) The project is applied research aiming at a design criterion for the optimized design of the complete jet pump systems under cavitation or non-cavitation conditions.
 - (e) This project is the first attempt in the optimum design of jet pump systems. It also summarized all previous methods of predicting cavitation performance of jet pumps. The project is now reoriented in the direction of more basic study of the flow inside the ejector.
 - (g) The project has resulted in a systematic method of designing jet pump systems. A cavitation predicting parameter, based on all previous published works by the present author or others, has been proposed. The work done currently has not produced a significant amount of results to be publishable.
 - (h) "Optimization of Jet Pump Systems," A. G. Hansen and T. Y. Na, ASME paper 66-FE-4, ASME 1966 Fluid Meeting, Denver, Colo., April 1966.
"A Jet Pump Cavitation Parameter Based on NPSH," A. G. Hansen and T. Y. Na, ASME paper 68-WA/FE-42, 1968 ASME Annual Meeting, New York, Dec. 1968.

- "Optimum Design of Water Jet Pumps," J. R. Cairns and T. Y. Na, Trans. ASME, J. Basic Engrg., Jan. 1969, pp. 62-68.
- "Optimal Design of Staged Jet-Pump Systems," J. R. Cairns, M. M. Sidhom and T. Y. Na, ASME paper, 68-WA/FE-41, 1968 ASME Annual Meeting, New York, Dec. 1968.
- "Jet Pump Cavitation," R. G. Cunningham, A. G. Hansen and T. Y. Na, ASME paper 69-WA/FE-29, 1969 ASME Annual Meeting, Nov. 16-20, Los Angeles, J. Basic Engrg., Trans. ASME, March 1970.

UNIVERSITY OF MINNESOTA, Department of Aerospace Engineering and Mechanics, Minneapolis, Minnesota 55455. Professor P. R. Sethna, Department Head.

(7488)

HYDRODYNAMIC STABILITY.

- (b) National Science Foundation.
- (c) Prof. Daniel D. Joseph.
- (d) Theoretical; basic research; M.S., Ph.D. theses.
- (e) This project consists of theoretical research on the stability of a broad class of fluid motions.
- (g) The implications of energy analysis for the stability of classical motions (Couette and Poiseuille flows in annuli, pipes, channels, etc., and variations on the Benard problem) are emphasized. A global theory of stability is sought in which linear theory, energy theory and the theory of branching solutions of the Navier-Stokes equations play unique and complementary roles.
- (h) "Stability of Frictionally Heated Flow," Physics of Fluids 8, No. 12, 2195-2200 (1965).
- "Nonlinear Stability of Boussinesq Equations by the Method of Energy," Archive for Rational Mech. and Analysis 22, No. 3, pp. 163-184 (1966).
- "Subcritical Convective Instability: Part I, Fluid Layers," with C. C. Chir, J. Fluid Mech. 26, Part 4, pp. 753-768 (Feb. 1966).
- "Subcritical Convective Instability: Part II, Spherical Shells," with S. Carmi, J. Fluid Mech. 26, Part 4, pp. 769-777 (Feb. 1966).
- "Stability of Axial Flow in a Concentric Annulus," with J. Mott, Physics of Fluids (Oct. 1968).
- "Stability of Hagen-Poiseuille Flow," with S. Carmi, accepted for publication in Quart. Appl. Math.
- "Eigenvalue Bounds for the Orr-Sommerfeld Equation," J. Fluid Mech., 33, Part 3, pp. 617-621 (1968).
- "Subcritical Instability and Exchange of Stability in a Horizontal Fluid Layer," with R. Goldstein and D. Graham, Physics of Fluids, Research Note, 11, pp. 903-904 (1968).
- "Convective Instability in a Temperature and Concentration Field," with C. C. Chir, Archive for Rational Mech. and Anal., 30, pp. 38-80 (1968).
- "Eigenvalue Bounds for the Orr-Sommerfeld Equation Part II," accepted for publication in J. Fluid Mech.
- "Stability of Parallel Flow between Concentric Cylinders," J. E. Mott and D. D. Joseph, The Physics of Fluids, Volume 11, Nov. 10, Oct. 1968.
- "Stability of Poiseuille Flow in Pipes, Annuli, and Channels," D. D. Joseph and S. Carmi, Quart. Appl. Math., Vol. XXVI, No. 4, Jan. 1969.

(7489)

THEORY OF TURBULENCE.

- (b) Department of Defense, ONR.
- (c) Prof. T. S. Lundgren.

- (d) Theoretical; basic research.
- (e) Approximate equations describing shear turbulence are proposed and solved for specific flow situations.
- (h) "Model Equation for Nonhomogeneous Turbulence," T. S. Lundgren, Physics of Fluids, 12, 485 (1969).

(7490)

COUPLED FLOWS IN DUCTS AND POROUS MEDIA.

- (b) National Science Foundation.
- (c) Gordon S. Beavers, Asst. Prof.
- (d) Theoretical and experimental; basic and applied research; M.S., Ph.D. theses.
- (e) The project involves research on a class of problems involving coupled parallel flows in a duct and in a porous medium which forms one or more of the duct walls. Flows in channels with non-porous walls are studied. The effect of a slip velocity at a channel wall through which fluid is injected is under investigation.
- (g) Work on the following aspects of the research program has been reported: (1) Fully-developed plane Poiseuille flow in a flat rectangular duct, one wall of which is a participating porous medium, has been studied experimentally. The existence of a slip velocity at the porous wall has been demonstrated and a model of the phenomenon, patterned after that of rarefied gas dynamics, has been proposed. (2) The flow characteristics of fibrous, porous media are being studied, with emphasis on the non-Darcy regime. (3) Experiments on the laminar-turbulent transition in flat rectangular ducts bounded by impermeable walls have been carried out using a variety of external disturbance sources. (4) The hydrodynamic development of laminar flow in rectangular ducts of various aspect ratios bounded by impermeable walls has been investigated experimentally. (5) The laminar-turbulent transition in a rectangular duct bounded by a porous wall is being studied experimentally and theoretically. (6) The effect of slip velocity on channel and pipe flows with fluid injection is being investigated.
- (h) "Non-Darcy Flow Through Fibrous, Porous Media," G. S. Beavers and E. M. Sparrow, J. Appl. Mech., Vol. 36, No. 4, December 1969.
- "Experiments on the Breakdown of Laminar Flow in a Parallel-Plate Channel," G. S. Beavers, E. M. Sparrow, and R. A. Magnuson, to be published in the Intl. J. Heat and Mass Transfer.
- "Experiments on Hydrodynamically Developing Flow in Rectangular Ducts of Arbitrary Aspect Ratio," G. S. Beavers, E. M. Sparrow, and R. A. Magnuson, to be published in the Intl. J. Heat and Mass Transfer.
- "Experiments on Coupled Parallel Flows in a Channel and a Bounding Porous Medium," G. S. Beavers, E. M. Sparrow, and R. A. Magnuson, to be published in Trans. ASME, J. Basic Engrg., 1970.
- "Effects of a Porous Bounding Wall on Turbulent Duct Flow," R. A. Magnuson, M.S. thesis, Univ. of Minn., Dec. 1969.

(7491)

VORTEX DEVELOPMENT IN JETS.

- (c) Gordon S. Beavers, Asst. Prof.
- (d) Theoretical and experimental; basic and applied research; Ph.D. thesis.
- (e) The growth of symmetric and alternating vortex streets in jets is studied for several jet configurations.
- (h) "Vortex Growth in Jets," G. S. Beavers and T. A. Wilson, Univ. of Minn. Research Report.

UNIVERSITY OF MINNESOTA, Department of Agricultural Engineering, St. Paul, Minnesota 55101. Dr. Landis Boyd, Department Head.

(7492)

EFFECTS OF AREAL AND TIME DISTRIBUTION OF RUNOFF SUPPLY ON RUNOFF HYDROGRAPHS.

- (b) Minnesota Water Resources Research Center and OWRR.
- (c) Prof. Curtis L. Larson.
- (d) Theoretical and experimental research; basic and applied research.
- (e) A mathematical watershed model, based on the unsteady flow equations, is being used to study the effects on non-uniform distribution of rainfall excess on hydrographs, especially on peak discharge. The patterns being used as input include variations in areal distribution, time distribution and storm movement. Watershed shape is also being varied.
- (g) Non-uniform distribution (in time or area) tends to increase peak discharge. Delayed time distributions tend to cause the highest peak discharges.
- (h) Reports in preparation.

(7493)

STUDY OF FACTORS AFFECTING CHANNEL PHASE OF RUNOFF PROCESS BY MEANS OF MATHEMATICAL MODELING.

- (b) Minnesota Water Resources Research Center and OWRR.
- (c) Professor Curtis L. Larson.
- (d) Theoretical and experimental research; basic and applied research.
- (e) A mathematical model of an idealized fourth order watershed, based on the unsteady flow equations, has been developed. The physical characteristics of the channel systems are varied systematically to determine their effects of watershed time parameters. Various combinations of duration and rate of rainfall excess are used as input and their effects on peak flow and time parameters are studied.
- (f) Complete.
- (g) The relation of peak flow of the model watershed to runoff amount is non-linear. Log time varied with both input rate and duration. Analysis of data not complete.
- (h) "Runoff Hydrographs for Mathematical Watershed Model," R. E. Machmeier and C. L. Larson, J. Hyd. Div., ASCE, Nov. 1968.

(7494)

HYDROLOGY OF SMALL WATERSHEDS.

- (b) Minnesota Agricultural Experiment Sta.
- (c) Prof. Curtis L. Larson.
- (d) Theoretical and experimental research; basic and applied research.
- (e) The land phase of the runoff process is being investigated. This includes several hydrologic processes. Current efforts are directed toward mathematical modeling of the process of infiltration and soil moisture movement.

(7495)

SUB-SURFACE IRRIGATION EFFICIENCY IN SANDY SOILS.

- (b) Agricultural Experiment Station.
- (c) Prof. Evan R. Allred.
- (d) Theoretical and field investigations.
- (e) Studies directed toward movement of water in selected sandy soil profiles when applied by various subsurface methods. Gamma-ray densi-

ter used to measure water movement in laboratory model for different soil conditions. Development of a mathematical model is planned to compare theoretical values with data obtained from laboratory model. Comparisons with field data are also planned.

(7496)

FLOW CHARACTERISTICS AND SETTLEMENT PATTERNS IN AN OXIDATION DITCH.

- (b) Agricultural Experiment Station.
- (c) Professor Evan R. Allred.
- (d) Theoretical and field investigations.
- (e) A laboratory scale model is being used to study the flow characteristics in an oxidation ditch, as used for the disposal of animal wastes. Various combinations of rotor speed, rotor design, immersion depth of rotor, total water depth and channel shape are employed to determine their effect on solid settlement patterns and operating efficiency.
- (g) Caution must be applied where the oxidation ditch is used to treat animal wastes, which by nature contain solids of widely varying specific gravities. Anaerobic conditions, as the result of poor circulation, may develop in certain portions of the ditch.

UNIVERSITY OF MINNESOTA, St. Anthony Falls Hydraulic Laboratory (see ST. ANTHONY FALLS listing).

UNIVERSITY OF MISSOURI - COLUMBIA, Department of Civil Engineering, Columbia, Missouri 65201. Dr. Adrian Paww, Department Chairman.

(5828)

SPILLWAY DISCHARGE COEFFICIENTS AND PRESSURE DISTRIBUTIONS AS A FUNCTION OF SPILLWAY SHAPE.

- (b) Univ. of Missouri, Engrg. Expt. Sta.
- (c) Dr. John J. Cassidy.
- (d) Experimental; basic research; M.S. thesis.
- (e) Discharge coefficients and pressure distributions are being determined experimentally for spillways with varying crest shapes.
- (f) Completed.
- (g) A dimensionless parameter involving minimum pressure on the crest and discharge was evolved and correlated with spillway shape. Experimental results for minimum pressure and discharge coefficients can be used to design a spillway crest for high-head operation at a particular desired minimum crest pressure.
- (h) "Designing Spillways for High-Head Operation," ASCE, J. Hyd. Div., March 1970. "Spillway Characteristics," M.S. thesis, Chii-ell Tsai, Civil Engrg. Dept., Univ. of Missouri.

(5829)

DISCHARGE MEASUREMENT IN TWO-DIMENSIONAL FLOW.

- (b) Missouri Water Resources Center.
- (c) Dr. Henry Liu.
- (d) Experimental; applied.
- (e) A new method of discharge measurement is being studied. The method involves the release of lighter-than-water particles on or near the floor of a channel, and the measurements of the horizontal distance traversed during their rise to the surface.
- (f) Completed.
- (g) Parameters influencing the accuracy of discharge measurement in two-dimensional, low-velocity

- flows have been available. The method is particularly applicable to such flow.
- (h) "Discharge Measurement Using Lighter-Than-Water Particles," Larry D. Martin, M.S. Thesis, Civil Engrg. Dept., Univ. of Missouri.
- (6076)
THE MOTION OF RIGID SPHERES IN A HIGHLY TURBULENT FIELD.
- (b) National Science Foundation.
(c) Dr. John J. Cassidy.
(d) Experimental basic research.
(e) A study is being made of the drag on spheres moving in a fluid field in which the turbulence scale is of the order of the sphere diameter.
(f) Completed.
- (6077)
IRROTATIONAL POTENTIAL FLOW OVER A SPILLWAY TOE CURVE.
- (b) U.S. Army Engrs., Waterways Experiment Sta.
(c) Dr. John J. Cassidy.
(d) Analytical; applied research.
(e) An analytical method is being developed for the determination of free-surface profiles and floor pressures for flow over a spillway toe curve of given shape.
(f) Completed.
(g) A Fortran program was devised which will predict the free-surface profile and boundary pressure distribution for flow over a spillway toe curve. The solution is in terms of boundary geometry, discharge, and total head.
(h) "Flow Over a Spillway Toe Curve, Final Report," Contract DACW 39-67-C-0001, U.S. Army Waterways Exp. Sta., Vicksburg, Miss., Aug. 1968.
- (6079)
DIFFUSION OF SEDIMENT.
- (c) Dr. Charles Lénau.
(d) Analytical; basic.
(e) An analytical analysis is being made of the diffusion of sediment in a turbulent open channel flow.
(f) Completed.
(g) Differential equations describing sediment concentration downstream from a sediment source in a uniform flow were solved.
(h) "Effect of Concentration on Sediment Distribution," ASCE, J. Hyd. Div., Sept. 1969.
- (6080)
HYDRAULIC CHARACTERISTICS OF AN ARTIFICIAL HEART.
- (b) Missouri Regional Medical Program.
(c) Dr. Allen T. Hjelmfelt, Jr.
(d) Experimental; applied.
(e) An experimental design of an artificial heart has been undertaken.
(f) Completed.
- (7497)
DYNAMIC SEPARATION OF SUSPENDED SOLIDS.
- (b) Office of Water Resources Research.
(c) Dr. A. T. Hjelmfelt, Jr.
(d) Experimental; basic.
(e) A study is being made of the efficiency which can be obtained in separating solids from fluids by passing the mixture through an orifice and selectively sampling the resulting concentration as a function of space.
(g) "Dynamic Separation of Solids," Jae-duck Lee, M.S. thesis, Civil Engrg. Dept., Univ. of Missouri, June 1970.

- (7498)
UNSTEADY PRESSURES IN SWIRLING FLOW.
- (c) Dr. John Cassidy.
(d) Experimental and analytical; basic.
(e) A study is being made of the conditions of flow arising in straight tubes after vortex breakdown.
(g) "Observations of Unsteady Flow Arising After Vortex Breakdown," J. Fluid Mech., March 1970.
- (7499)
DRAFT-TUBE SURGING IN HYDRAULIC TURBINES.
- (b) U.S. Bureau of Reclamation.
(c) Dr. John Cassidy.
(d) Experimental; basic.
(f) Completed.
(g) The occurrence of draft-tube surging and the unsteady resulting pressure-frequency and amplitude were correlated with the angular-momentum and linear-momentum fluxes in the draft tube.
(h) "Experimental Study and Analysis of Draft-Tube Surging," Rept. No. HYD-591, U.S. Bureau of Recl., Denver, Colo., May 1969.
- (7500)
CIRCULATION IN SHALLOW LAGOONS.
- (b) Missouri Water Pollution Control Board.
(c) Dr. Henry Liu.
(d) Experimental and analytical; basic.
(e) Circulation patterns in shallow lagoons as a result of wind are being studied in a wind tunnel and analytically with a digital computer.
(h) "Wind-Induced Circulation in Shallow Lagoons," Himerio Perez, M.S. thesis, Civil Engrg. Dept., Univ. of Missouri, Feb. 1970.
- UNIVERSITY OF MISSOURI - ROLLA, School of Engineering, Department of Chemical Engineering, Rolla, Missouri 65401. Dr. J. L. Zakin, Professor.
- (6404)
EFFECT OF POLYMER STRUCTURE ON DRAG REDUCTION.
- (c) Dr. Jacques L. Zakin or Dr. Gary K. Patterson.
(d) Experimental, basic research, M.S. thesis.
(e) The effectiveness of polymer additives in causing drag reduction is being studied in terms of molecular weight, molecular conformation, molecular structure and concentration as well as mean velocity and diameter of conduit. The objective is to obtain quantitative relationships among these variables.
(g) Previous work has shown that molecular conformation in solution, molecular weight, molecular structure and concentration, mean velocity and tube diameter all affect the level of drag reduction and the type of drag reduction observed in polymer solution. Low values of the molecular rigidity, β , and high values of the entanglement capacity of the polymer chain, $m' = M/(M \text{ for critical entanglement})$ have been shown to be important for significant drag reduction.
(h) "Prediction of Drag Reduction with a Viscoelastic Model," G. K. Patterson and J. L. Zakin, AIChE J., 14, 434 (1968).
"The Effect of Molecular Characteristics of Polymers on Drag Reduction," G. C. Liaw, J. L. Zakin and G. K. Patterson, submitted to AIChE J.

- (6405)
TURBULENCE INTENSITIES IN DRAG REDUCING ORGANIC SOLUTIONS.
- (c) Dr. Jacques L. Zakin or Dr. G. K. Patterson.
(d) Experimental; basic research; Ph.D. thesis.

- (e) Details of the turbulence structure of drag reducing and non-drag reducing solutions are being investigated. Turbulence intensities, frequency spectra, integral scales and other turbulence quantities are being compared for drag reducing and non-drag reducing solutions.
- (g) The results of turbulence measurements in solvents using wedge probes closely check the accepted values for measurements in air. A comparison of wedge, parabolic, cone and cylindrical hot-film probes showed the wedge and parabolic probes gave identical results while cone probes gave slightly low intensities. Cylindrical data were erratically because of eddy shedding. In viscoelastic solutions, high and low values of turbulence intensities are observed depending on the flow velocity. The frequency response of hot-film wedge probes was shown to be flat up to 100 cps so that frequency response of the probe can not account for these discrepancies.
- (h) "Effect of Probe Geometry on Turbulence Measurements in Liquids Using Hot-Film Constant Temperature Anemometry," J. M. Rodriguez, G. K. Patterson and J. L. Zakin, *J. Hydraulics*, 4, 16, (1970).
"Response of Hot-Film Wedge Probes in Viscoelastic Fluids," J. M. Rodriguez, G. K. Patterson and J. L. Zakin, in *Proc. Intl. Symp. on Turbulence Measurements in Liquids*, Gordon & Breach, in press.
- (6407)
DRAG REDUCTION IN ORGANIC SOAP SOLUTIONS.
(c) Dr. Jacques L. Zakin or Dr. Gary K. Patterson.
(d) Experimental; basic research; M.S. thesis.
(e) While polymer solution drag reduction has been widely studied, little effort has been given to soap additives which may be more effective drag reducers. The effect of soap type and concentration and the influence of flow variables (flow rate and diameter) are being investigated.
- (g) In soap systems in non-polar solvents, diameter and velocity effects appear to be similar to those in polymer solutions. Soap solutions are sensitive to aging and under certain conditions to mechanical shear.
- (h) "Exploratory Drag Reduction Studies in Non-Polar Soap Systems," I. Radin, J. L. Zakin and G. K. Patterson in "Viscous Drag Reduction," C. S. Wells, Ed., Plenum Press, 1969.
- (6408)
VISCOSITY OF POLYMER SOLUTIONS.
(c) Dr. Jacques L. Zakin or Dr. Kenneth G. Mayhan.
(d) Experimental; basic research; M.S. thesis.
(e) The effects of polymer concentration, molecular weight, solvent-polymer interactions and polymer structure on viscosity are being investigated.
- (g) Viscosity concentration data of a number of polymer solutions in good solvents fit a single curve when plotted as $\eta_{sp}/C[\eta]$ vs $k'(\eta)$ C up to the region of incipient molecular overlap.
- (h) "The Effect of Concentration on the Viscosities of Solutions of Linear Flexible High Polymers," L. Y. Chou and J. L. Zakin, *J. Colloid & Interface Sci.*, 25, 547 (1967).
"The Effect of Concentration on the Viscosity of Dilute and Moderately Concentrated Polymer Solutions," H. Luh, M.S. thesis, Univ. of Missouri - Rolla - 1967.
- (7501)
SOLID SUSPENSION DRAG REDUCTION.
(b) Petroleum Research Fund of the American Chemical Society.
- (c) Dr. J. L. Zakin or Dr. G. K. Patterson.
(d) Experimental, basic research, Ph.D. thesis.
(e) An investigation of the particle, fluid and flow variables influencing drag reduction in the flow of solid suspensions.
- (7502)
MEASUREMENT OF COMPLEX MODULUS IN DILUTE POLYMER SOLUTIONS.
(c) Dr. Gary K. Patterson.
(d) Experimental, basic research, Ph.D. thesis.
(e) Development of instrument capable of measuring complex shear modulus at audio frequencies in dilute (below interaction) concentrations. Studies of effect of concentration and molecular weight dispersion on complex modulus.
- (7503)
SEGREGATION INTENSITIES AND REACTION RATES IN A STIRRED TANK REACTOR.
(c) Dr. Gary K. Patterson.
(d) Theoretical, basic research, Ph.D. thesis.
(e) Segregation intensity and reaction completion distributions are being calculated for stirred tank flow reactors under various conditions. Results of recent research on mixing are being used in the calculations. Extension from steady state operation to transient conditions is now being made.
- (g) Comparisons with the little experimental data available indicate that the approach gives very realistic results with and without reaction.
- (h) "Segregation Intensity Distribution in a Tank Mixer with and without Second-Order Reaction," G. K. Patterson, presented at *Chemica* 70, Melbourne-Sidney, Australia, Aug. 1970.
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- UNIVERSITY OF MISSOURI - ROLLA, Department of Civil Engineering, Rolla Missouri 65401. Joseph H. Senne, Department Chairman.
- (029W)
SPATIAL BEHAVIOR OF ROUGHNESS IN LABORATORY WATER-SHEDS.
Reported in Water Resources Research Catalog.
- (114W)
SPILLWAY DESIGN FLOODS FOR SMALL DAMS IN MISSOURI.
Reported in Water Resources Research Catalog.
- (6287)
MODIFIED STATION-YEAR METHOD FOR FLOOD FREQUENCIES.
(c) Dr. T. E. Harbaugh.
(d) Design.
(e) Determination of flood peaks for small drainage areas in Missouri based on physiographic data.
- (7504)
EFFECT OF RAINDROP IMPACT ON OVERLAND FLOW.
(c) Dr. T. E. Harbaugh.
(d) Experimental.
(e) Work is being performed in the laboratory to determine the effect of raindrop impact as a contributing factor in the resistance to flow for short overland flow conditions.
- (g) Ph.D. dissertation pending.
- (7505)
TIME SEQUENCED DAM FAILURES.
(b) NDEA.
(c) Dr. T. E. Harbaugh.
(d) Experimental.
(e) Determination of the influence of a controlled

breaking of a dam upon the ensuing downstream flood wave.

- (g) Ph.D. dissertation pending.

(7506)

EVALUATION OF A SINGLE LAYER OF GRADED GRAVEL AS A PROTECTIVE FILTER ON EMBANKMENT SLOPES.

(b) Office of Water Resources Research.

(c) C. D. Muir, Assoc. Prof.

(d) Experimental.

(e) The basic purpose of this investigation is to determine the effect of thickness and gradation on the ability of a single graded filter layer to prevent the migration of finer particles through the layer.

- (g) Master's thesis pending.

(7507)

A SENSITIVITY ANALYSIS OF THE SPATIALLY VARIED UNSTEADY FLOW EQUATIONS.

(c) Dr. T. E. Harbaugh.

(d) Theoretical.

(e) Computer solution of the spatially varied flow equations are being performed for various boundary, finite difference, mesh sizes, and inputs to determine the sensitivity of the equations to a variety of parameters.

- (g) Ph.D. dissertation pending.

UNIVERSITY OF MISSOURI - ROLLA, School of Engineering, Department of Engineering Mechanics, Rolla, Missouri 65401. R. F. Davidson, Department Chairman.

(7508)

CALCULATION OF START-UP FLOW VELOCITY IN A LONG CIRCULAR TUBE.

(c) Dr. Xavier J. R. Avula.

(d) Analytical and experimental, basic research.

(e) A combination of experimental and analytical methods was used to determine the velocity of fluid in a starting flow process in a long circular tube. The developing pressure gradient was used in the solution of Navier-Stokes equations. Expression for developing velocity was obtained by Laplace transformation technique.

(f) Completed.

(g) Velocity profiles were calculated for the pressure gradient developed in a starting flow process. A comparison of the velocity profiles with those under constant pressure gradient revealed significant difference. The assumption of constant pressure gradient in a starting flow process is unsatisfactory.

- (h) "A Combined Method for Determining Velocity of Starting Flow in a Long Circular Tube," X. J. R. Avula, J. Phys. Soc. Japan, 27, 2, Aug. 1969.

(7509)

STARTING FLOWS IN THE ENTRANCE REGION OF A CIRCULAR TUBE - CONSTANT INLET VELOCITY CASE.

(c) Dr. Xavier J. R. Avula.

(d) Theoretical, basic research.

(e) Suddenly started laminar flow in the entrance region of a circular tube, with constant inlet velocity, was investigated analytically by using the integral momentum approach. A closed-form solution to the integral momentum equation was obtained by the method of characteristics.

(f) Completed.

(g) Expressions for boundary layer thickness, entrance length, velocity profile and pressure gradient were obtained. Boundary layer development close to the inlet compared favorably with

flat plate solution. The solution approaches Poiseuille's solution asymptotically.

- (h) "Analysis of Suddenly Started Laminar Flow in the Entrance Region of a Circular Tube with Constant Inlet Velocity," X. J. R. Avula, Appl. Scientific Res., 21, p. 248, Oct. 1969.

(7510)

A STUDY OF THE EFFECTS OF PRESSURE-INDUCED VISCOSITY CHANGES ON THE FLUID FLOW CHARACTERISTICS IN A CIRCULAR TUBE.

(b) National Science Foundation.

(c) Dr. Robert L. Davis.

(d) Analytical experimental; basic research for Master's thesis.

(e) A method of determining the response of fluids under high pressure to quick-release into the atmosphere is presented. Velocity profiles for constant and variable viscosity cases were calculated by using the experimentally measured pressure decay in the reservoir.

(f) Completed.

(g) The assumption of constant viscosity was found to be valid for pressures below 10,000 psi. Variable viscosity had to be considered for pressures over 10,000 psi. The magnitudes of the velocities were found to be lower than those obtained by the constant viscosity solution. Velocities were found to become closer as the pressure decreased.

MOBIL RESEARCH AND DEVELOPMENT CORPORATION, Field Research Laboratory, P. O. Box 900, Dallas, Texas 75221. J. S. McNiel, Manager.

(6391)

TURBULENT FLOW BEHAVIOR OF RHEOLOGICALLY COMPLEX FLUIDS.

(c) J. G. Savins, Research Assoc.

(d) Experimental and theoretical applied research.

(e) Studies of turbulent flow in aqueous and non-aqueous media containing high molecular weight polymers, micelle-forming materials, and particulates, and exhibiting drag reducing activity. Objectives include understanding of different manifestations of drag reduction phenomena displayed in internal and external flows, and under conditions similar to those encountered in practical engineering applications.

(g) In devising models and scale-up methods relating to turbulent flow of rheologically complex fluids, it is desirable to describe, identify, and classify the features of categories of drag reduction behavior observed in real systems. Recent work has led to the formulation of a structuring scheme in which three categories of behavior in micelle-type drag reducers, and flow categories of behavior in polymeric-type drag reducers are identified (see h).

(h) "Contrasts in the Solution Drag Reduction Characteristics of Polymeric Solutions and Micellar Systems," J. G. Savins, In "Viscous Drag Reduction," pp. 183-212, C. S. Wells, Jr., Ed., Plenum Press, New York (1969).

(7511)

COMPLEX FLUID BEHAVIOR.

(c) J. G. Savins, Research Associate.

(d) Experimental and theoretical applied research.

(e) Seek new technology relating to rheologically complex flow phenomena. Activities of interest include ducted flows of solutions, slurries, emulsions, foams, and micelle-forming systems,

near and non-viscometric flows, development of instrumentation, and improvement of data reduction and analysis techniques.

- (h) "Non-Newtonian Flow through Porous Media," J. G. Savins, Ind. and Engr. Chem., 61, (10), pp. 18-47 (1969).
"Radial (Secondary) Flows in Rheogoniometric Devices," J. G. Savins and A. B. Metzner (University of Delaware), Rheologica Acta, (in press).
"A Comparison of Differential and Integral Descriptions of the Annular Flow of a Power-Law Fluid," G. C. Wallick and J. G. Savins, J. Soc. Petr. Engr., pp. 311-314, Sept. (1969).

MONTANA STATE UNIVERSITY, Department of Agricultural Engineering, Agricultural Experiment Station, Bozeman, Montana 59715. Professor Charles C. Bowman, Department Head.

(4664)
EFFICIENT APPLICATION OF IRRIGATION WATER BY SURFACE FLOODING METHODS.

- (d) This is a study to develop design criteria for more efficient application of irrigation water by flooding method. This is basic research at the present time, but will be applied research immediately upon completion of the first phase.
(e) Automation of systems is also included in these studies.
(h) "Vegetative Density Meter," C. C. Bowman and R. Stitt, Mont. Agric. Expt. Sta. Bul. No. 611, 1965.

MONTANA STATE UNIVERSITY, Department of Civil Engineering and Engineering Mechanics, College of Engineering, Bozeman, Montana 59715. Dr. Glen L. Martin, Department Head.

(115W)
DRAINAGE CORRELATION RESEARCH PROJECT.
WRRC 2.0710.

(116W)
DEVELOPMENT OF A STATE WATER PLANNING MODEL.
WRRC 6.0325.

(117W)
EVALUATION OF HYDROLOGIC INSTRUMENTATION ON MAYNARD CREEK WATERSHED.
WRRC 7.0073.

- (7512)
WATER RESOURCES IN SOURDOUGH AND MIDDLE CREEK WATERSHEDS -- A COMPARATIVE STUDY OF QUALITY AND HYDROLOGY.
(c) T. T. Williams, Assoc. Prof.
(d) Field investigation, applied research, not for thesis.
(e) Comparison of water quality and hydrology of two similar, adjacent watersheds, one of which receives extensive recreational use, the other having been closed to public access for over 50 years.
(g) Results to date are meager but indicate that the open watershed produces fewer suspended and dissolved solids than does the closed watershed. The preliminary hypothesis is that wildlife (mostly deer and elk) pollute the closed stream to a greater extent than the open.

(7513)

PIPELINE TRANSPORT OF WOODCHIP AND WATER MIXTURES.

(b) U.S. Dept. of Agriculture, Forest Service.

(c) Dr. W. A. Hunt.

(d) Theoretical and experimental research. Applied research including master's and doctoral thesis studies.

(e) The following studies are in progress: (1) investigations of head losses in straight pipes transporting mixtures of woodchips and water; (2) development of a mechanical system for injecting large quantities of woodchips continuously into a pipeline system; (3) corrosion effects of water and woodchip mixtures on steel pipes.

- (g) (1) A computer program to study the feasibility of any proposed woodchip pipeline was completed; (2) tests showing effects of woodchips in varying concentrations on (a) valve characteristics, (b) pump characteristics, (c) head losses in axisymmetric expansions were completed, (d) an analysis of the waterhammer effects on a proposed injection system was conducted by using the method of characteristics; (4) an instrumentation system for obtaining "on line" results from a digital computer was developed.
(h) "Analysis of Hydraulic Transients in an Injection Device for Two-Phase Flow Systems," G. A. Hendrix, M.S.C.E. thesis, Montana State Univ., Bozeman, 1968.
"Optimization of Pipelines Transporting Solids," I. C. Hoffman and W. A. Hunt, J. Pipeline Division, ASCE, 94 (PL1), Oct. 1968.
"Economic Analysis of a Wood-Chip Pipeline," W. A. Hunt, Forest Products J., 17(9), Sept. 1967.
"A Method for Determining the Moisture Content and Specific Gravity of Woodchips in a Pressurized Water System," R. E. Schmidt, Tappi, 51 (4), April 1968.

NEWARK COLLEGE OF ENGINEERING, Department of Mechanical Engineering, 323 High Street, Newark, New Jersey 07102. George B. Thom, Department Chairman.

(7514)

ISOTHERMAL SLIP FLOW IN THE ENTRANCE OF A TUBE AND A PARALLEL PLATE CHANNEL.

(c) Dr. R. Y. Chen, Assistant Professor.

(d) Theoretical, basic research.

(e) Compressible isothermal flow in the entrance region with slip at the wall is analyzed with integral method. The centerline velocity distribution and the excess pressure drop over the fully developed incompressible flow are presented in figures for different inlet Mach numbers.

(f) Completed.

(g) The flow may be considered as incompressible when the inlet Mach number is about or less than 0.07 for gas with specific heats ratio of 1.40. The errors in centerline velocity and excess pressure drop, in this case, are less than 5% and 10%, respectively.

(h) "Slip Flow in the Entrance of a Tube," R. Y. Chen, ASME, 91D, 3, 545-549, Sept. 1969.

(7515)

STEADY-STATE AND DYNAMIC ANALYSES OF UNDERWATER TOWING CABLES.

(b) Naval Undersea Research and Development Center.

(c) Dr. Jeffrey W. Schram, Assistant Professor.

(d) Theoretical; applied research.

(e) Computer simulation of an underwater towed system as the towing ship is negotiating a turn. The

towed body has lifting surfaces, which must be taken into account when computing the lower boundary condition of the cable. The configuration of the cable is obtained as the result of this simulation.

- (f) Completed.
- (g) For the cases studied, the towed body showed significant movement out of the towing plane as the turn rate increased. Work is now proceeding to change the rudder setting on the towed body so that it is made to follow the ship in the towing plane.

NEW YORK, STATE UNIVERSITY OF, AT BUFFALO, Department of Civil Engineering, Buffalo, New York 14214. Dr. Ralph R. Rumer, Department Chairman.

(6045)

DYNAMIC MODEL STUDY OF LAKE ERIE.

- (b) Federal Water Pollution Control Admin., Dept. of Interior.
- (d) Experimental and theoretical.
- (e) A vertically-distorted Froude model of Lake Erie housed in a rotating laboratory is being operated. The purpose of the investigation is to study the response of the water movement in the model lake to various physical inputs such as inflows, outflows, and wind stress. The effect of the earth's rotation is included by way of the rotating laboratory.
- (g) Results to date include measurements of water level response during mass oscillation, residence time of tracers entering the lake through the Detroit River, and surface circulation patterns for the isothermal lake system with the inflow of the Detroit River and the outflow of the Niagara River, surface and subsurface circulation patterns in the presence of a westerly wind and the development of a mathematical model for prediction of pollutant distribution in the model lake.
- (h) "Circulation Studies in a Rotating Model of Lake Erie," R. Rumer and L. Robson, Proc. 11th Conf. on Great Lakes Research, IAGLR 1969.
- "Wind-Induced Circulation Pattern in a Rotating Model of Lake Erie," P. Buechi, and R. Rumer, Proc. 12th Conf. on Great Lakes Research, IAGLR 1969.
- "Circulation Patterns and a Predictive Model for Pollutant Distribution in Lake Erie," J. Howell, K. Kiser and R. Rumer, Proc. 13th Conf. on Great Lakes Research, IAGLR, 1970.
- "Circulation in an Idealized Rectangular Basin," R. Lai and R. Rumer, Proc. 13th Conf. on Great Lakes Research, IAGLR, 1970.

(6046)

SALT WATER INTRUSION INTO LAYERED STRATA.

- (d) Analytical.
- (e) Purpose of the study was to determine the position of the salt water-fresh water interface in coastal aquifers composed of several homogeneous layers of differing permeabilities.
- (f) Completed.
- (h) "Salt Water Interface in a Layered Coastal Aquifer," R. Rumer and J. C. Shiau, Water Resources Res., Vol. 4, No. 6, p. 1235-1248, Dec. 1968.

(6047)

EROSION OF COHESIVE SOILS AND CHANNEL STABILIZATION.

- (b) Agricultural Research Service, USDA.
- (c) Dr. Robert Paaswell, Associate Professor.
- (d) Experimental and analytical.

- (e) The purpose of the study is to determine the effect of shear strength, density and structure of a cohesive bed as they affect the initiation and rates of erosion by flowing water. Equipment for consolidation of large clay samples and for the hydraulic testing is completed and testing is underway.
- (h) "Erosion of Cohesive Soil and Channel Stabilization: State of Knowledge," E. Partheniades and R. Paaswell, Dept. of Civil Eng. Rept. No. 19, Oct. 1968.
- "Erosion of Cohesive Soil and Channel Stabilization: Behavior of Cohesive Soils," R. Paaswell and E. Partheniades, Dept. of Civil Engineering, Rept. No. 19, Oct. 1968.
- "A Large Scale Uniaxial Consolidation Device," R. Paaswell, Proc. Specialty Conf. on Advances in Consolidation Theories for Clays, VII Intl. Conf. on Soil Mech. & Found. Engrg.

(6049)

TURBULENCE CHARACTERISTICS OF FREE SURFACE FLOWS WITH VARIABLE BOTTOM ROUGHNESS.

- (b) Agricultural Research Service, USDA.
- (c) Mr. Paul Blinco.
- (d) Experimental.
- (e) The purpose of the study is to correlate turbulence characteristics measured by bot-film probes with bed roughness. Experiments are being conducted in a tilting flume with removable false bottoms of variable roughness heights and patterns.

NEW YORK, STATE UNIVERSITY OF, AT STONY BROOK, Department of Mechanics, College of Engineering, Stony Brook, Long Island, New York 11790. Professor Richard S. L. Lee, Department Chairman.

(7519)

BEHAVIOR OF FIREBRANDS IN A TURBULENT SWIRLING NATURAL CONVECTION PLUME ABOVE A FIRE WHIRL.

- (b) National Science Foundation.
- (d) Experimental and theoretical; basic research.
- (e) In recent years, the control of forest fires has become a problem of increasing concern and consequently the understanding of the mechanism by which a free burning fire spreads has been the central objective of much directed efforts. It is generally accepted that such a fire spreads in ways intimately related to the convective air movements in and above the fire. From knowledge gained in some most recent large-scale free burning fire experiments and observations, ignition of unignited regions of fuel bed away from the fire by firebrands carried up and thrown out by the turbulent swirling natural convection plume above a fire whirl has been identified as one of the potentially most hazardous and the least understood of the mechanisms by which a free burning fire spreads. The principal investigator's previously completed plume studies readily supply him with the essential elements of the ground work necessary for the investigation of such a challenging and far more complicated problem. The present investigation consists of two major items. One is a combined theoretical and experimental research of the behavior of firebrands in a turbulent swirling gas-firebrand two-phase natural convection plume above a fire whirl and in the surrounding ambient air. The other is a corresponding research in a tornado-like fire whirl caused by the wind shear action of the ambient atmosphere.
- (g) In the area of the origin of fire whirls, the

- interaction between ambient wind shear and the natural convection plume has been identified as the controlling mechanism in the instability of the flow field. In the area of the firebrand trajectory studies, the two-phase interaction and the burning characteristics of the firebrand material are found to contribute overwhelmingly the dynamics of the firebrand.
- (h) "The Formation of Multiple Fire Whirls," 12th Intl. Symp. on Combustion, pp. 265-273, 1969.
 "Behavior of Spherical Solid Particles Released in a Laminar Boundary Layer along a Flat Plate," Appl. Scientific Res., Vol. 20, No. 6, p. 465, 1969.
 "Particle Migrations in Laminar Mixing of a Suspension with a Clean Fluid," (with Bernard Otterman), presented at Symp. on Flow of Fluid-Solid Mixtures, Intl. Union Theor. and Appl. Mech., Univ. of Cambridge, Cambridge, England, March 24-29, 1969. Also in Zeit. Angewandte Math. Und Phys. (ZAMP), Vol. 20, Fasc. 5, pp. 730-749, 1969.
 "Study of Firebrand Trajectories in a Turbulent Swirling Natural Convection Plume," Combustion and Flame, Vol. 13, pp. 1-11, 1969.
 "Particulate Velocity and Concentration Profiles for the Case of Laminar Flow of a Suspension over a Flat Plate," Proc. Inst. Fluid Mech. and Heat Transfer, Monterey, Calif., June 1970.
- (7520)
 A MAN OF HYDRAULICS: HENRI DE PITOT 1695 - 1771.
 (c) Professor Rene Chevray.
 (d) History of hydraulics.
 (e) To present the contribution made by Pitot in the field of hydraulics at the beginning of the 18th century.
 (f) Completed.
 (g) Technical biography of H. de Pitot.
 (h) Proc. ASCE, J. Hyd. Div., Vol. 95, No. HY4, July 1969.
- (7521)
 TWO SPECIES CHEMICAL REACTIONS IN TURBULENCE.
 (b) Natl. Science Foundation.
 (c) Professor Edward E. O'Brien.
 (d) Theoretical and experimental, basic research.
 (e) To investigate reaction surfaces and their role in controlling mixing rates for fast and very fast reactions in turbulence.
 (g) Theoretical investigations concerning the role of spectral evolution and the manifestation of reaction surfaces in terms of fluctuation moments are in process. Experimental measurements of reactions in the mixing wake behind a flat plate have begun.
- (7522)
 ONE SPECIES REACTIONS IN HOMOGENEOUS TURBULENCE.
 (b) Natl. Science Foundation.
 (c) Professor Edward E. O'Brien.
 (d) Analytical, basic research.
 (e) To develop closure approximations which satisfy all known invariances, and which accurately mimic exact solutions for stochastically distributed reactants.
 (f) Completed.
 (g) Statistical independence of turbulent mixing and reactions for these systems without reaction surfaces yields quantitatively satisfactory predictions.
 (h) "Decaying Second Order Isothermal Reaction in Final Period Turbulence," E. E. O'Brien, Physics of Fluids, 9, 1 (1966).
 "Closure Approximations Applied to Stochastically Distributed Second Order Reactants," Physics of Fluids, 9, 8 (1966), E. E. O'Brien.
 "A Closure for Stochastically Distributed Second Order Reactants," E. E. O'Brien, Physics of Fluids, 11, 9 (1968).
 "A Quantitative Test of the Direct Interaction Equation for Isotropic Turbulent Mixing under a Second Order Chemical Reaction," E. E. O'Brien, Physics of Fluids, 11, 10 (1968).
 "Lagrangian History Direct Interaction Equation for Isotropic Turbulent Mixing under a Second Order Chemical Reaction," E. E. O'Brien, Physics of Fluids, 11, 11 (1968).
 "A Postulate of Statistical Independence for Decaying Reactants in Homogeneous Turbulence," E. E. O'Brien, Physics of Fluids, 12, 10 (1969).
 "A Closure for Stochastically Distributed Reactants," E. E. O'Brien and R. M. Eng, Physics of Fluids, 12, 9 (1969).
- (7523)
 SAILING YACHT RESEARCH.
 (b) Laboratory and field project.
 (c) Professor Walter S. Bradfield.
 (d) Experimental and field investigation, applied research.
 (e) Development of methods of predicting and measuring sailing vehicle performance; development of a hydrofoil sailing vehicle; development of a method for full scale wind load measurement in the field.
 (h) Marine Technology, January 1970, p. 21.
- (7524)
 TURBULENCE MEASUREMENTS IN THE WAKE OF A THIN FLAT PLATE.
 (b) Air Force Office of Scientific Research.
 (c) Professor Rene Chevray.
 (d) Experimental, basic research.
 (e) To offer a critical test of the boundary layer calculation techniques since this flow corresponds to the development of a turbulent boundary layer with zero pressure gradient when the wall shear is suddenly removed at the trailing edge.
 (f) Completed.
 (g) The turbulent boundary layers on the two sides of the flat plate merge slowly and transform into the wake as the sudden disappearance of the wall shear diffuses outward. In other aspects the wake region behaves as expected. The large scale quasi-periodic motion often associated with wakes of two-dimensional blunt bodies is conspicuously absent.
 (h) AIAA J., Vol. 7, No. 8, August 1969.
- (7525)
 TEMPERATURE COMPENSATED LINEARIZER FOR HOT-WIRE ANEMOMETER.
 (b) AFOSR and ONR.
 (c) Professor L. S. G. Kovaszny (Johns Hopkins) and Professor R. Chevray.
 (d) Analytical and experimental, basic research.
 (e) To linearize the output for low velocity hot-wire anemometry.
 (f) Completed.
 (g) A detailed analysis of transistor chains used to generate the desired function is presented. The frequency response of the complete circuit proved very satisfactory. Special attention was given to compensation for temperature sensitivity inherent to solid state devices.
 (h) The Review of Scientific Instruments, Vol. 40, No. 1 Jan. 1969.

(7526)

FLOW OF LIQUID THROUGH CAPILLARY-POROUS WICK IN A HEAT PIPE.

- (c) Professor Lin-shu Wang.
- (d) Experimental, basic research.
- (e) The capability of a heat pipe to transfer heat is limited by the maximum flow rate of condensed liquid through porous wick. Our objective is to determine the maximum flow rates for various liquids commonly used as working fluids in heat pipes.

(7527)

THE FLUX OF HEAT AND MATTER THROUGH PROGRESSIVE WAVES.

- (c) Professor Edward E. O'Brien.
- (d) Theoretical, basic research.
- (e) To determine by exact analytic solution the role of waves in producing changes in mean and fluctuating scalar fields near an interface. Both thin liquid layers on solid surfaces and boundary layers on deep water are investigated.
- (f) Completed.
- (g) Fluctuation levels are lower by several orders of magnitude than those measured in the sea surface or in the laboratory. Simple surface wave enhanced mixing cannot therefore be the explanation of observed fluctuations. Waves on vertical liquid layers at moderate Prandtl numbers may play a significant role in heat transfer.
- (h) "On the Flux of Heat Through Laminar Wavy Liquid Layers," E. E. O'Brien, J. Fluid Mech., Vol. 28, part 2, 295-303, 1967.
"Surface Temperature and Heat Flux Variation at a Wavy Water-Air Interface," E. E. O'Brien and T. Omholt, J. Geophys. Res., 74, 13, 1968.
"The Effects of Progressive Waves on Convective Transfer," T. Omholt, Ph.D. thesis, Dept. of Mechanics, S.U.N.Y. at Stony Brook, March 1970.

THE CITY COLLEGE OF THE CITY UNIVERSITY OF NEW YORK, School of Engineering, Department of Civil Engineering, Fluid Mechanics Laboratory, New York, N. Y. 10031.

Professor Norman C. Jen, Laboratory Director.

(6185)

CHANGES IN INITIATION OF SEDIMENT MOTION DUE TO FLOW OBSTRUCTION BY PIERS OR SILLS.

- (c) Dr. Walter Rand.
- (d) Theoretical and experimental; applied research; master's thesis.
- (e) If hydrodynamic forces acting on an erodible bed reach values at which sediment motion is impending, a critical or threshold condition is reached. A structure (a pier or sill), if placed in the channel will change flow conditions, and erosion will develop. The principles of sediment transportation mechanics are used, and experiments with sediment beds of impending motion are conducted, to determine the erosion characteristics as functions of the geometry of the structure, and of the degree of obstruction. Using impending motion conditions as a reference, similarity laws for the erosion pattern will be developed.
- (g) Preliminary experiments with a rectangular channel indicate that the erosion length downstream of sills is a function of the Froude number, provided the impending motion conditions are used as reference.

(6186)

A FLEXIBLE APPROACH TO THE DESIGN OF STILLING BASINS.

- (c) Dr. Walter Rand.
- (d) Theoretical, experimental; development, design.

- (e) Adopting a generalized concept, a spillway-stilling basin complex can be considered as consisting of an entrance structure, a main basin and an after-basin.

The present knowledge on flow under gates and over drop structures, spillways, sills, steps, and baffles is applied to development of a design method in which the design of each structural element is determined individually to achieve the best possible solution for a particular set of conditions. The method would be an extension of current design methods for hydraulic jump stilling basins applicable to cases such as very low tail-water, intermittent operation, and rocky channels where the current methods do not offer straightforward solutions. Models are used for verification as the design is evolved.

- (g) The approach has been used to analyze some of the current design methods. The agreements found and the interpretations of the current methods indicate that further progress is possible. These analyses are published in (h).
- (h) Discussion of "The Hydraulic Design of Stilling Basins," Walter Rand, ASCE, Proc., Vol. 84, Paper 1616, April 1958.
Discussion of "Straight Drop Spillway Stilling Basin," J. Hyd. Div., ASCE, Vol. 92, No. HY 1, Jan. 1966.

(7055)

WATER POLLUTION - DISPERSION AND TRANSPORT PROCESS ALONG A COAST.

- (c) Professor Norman C. Jen and Dr. F. F. Yeh.
- (d) Experimental; applied research; for Master's thesis.
- (e) By simulating an actual condition along a coast, the processes of dispersion and transport of dissolved and/or other particles are considered to be important for water pollution problems. The waves, winds and current can be introduced separately or combined together. The test tank is 20 ft. by 10 ft. and 2 ft. in depth.
- (f) The construction has been recently completed. The investigations are in progress.

NEW YORK UNIVERSITY, Courant Institute of Mathematical Sciences, 251 Mercer Street, New York, N. Y. 10012.
Professor Cathleen S. Morawetz.

(6572)

THEORETICAL PROBLEMS IN HYDRODYNAMICS.

- (b) Office of Naval Research, Mechanics Branch.
- (d) Theoretical research; basic.
- (e) Research in the field of classical hydrodynamics in incompressible fluids. Special numerical studies of ship wave motion.
- (g) Reformulation of the Stoker-Peters integral equation for the ship wave problem.

NEW YORK UNIVERSITY, Department of Chemical Engineering, School of Engineering and Science, University Heights, New York, N. Y. 10453. Professor John Happel, Department Chairman.

(6217)

SEDIMENTATION OF TWO PROLATE SPHEROIDS IN CLOSE PROXIMITY.

- (d) Experimental; basic research.
- (e) Mutual interaction of two prolate spheroids sedimenting in a viscous fluid are continuing to be investigated. Presently, the relationship relat-

- ing the torque created by the sedimentation of two spheroids aligned vertically on the same axes to the angle made by the two spheroids are being studied.
- These studies and theoretical treatment apply only in the creeping motion region ($\text{Reynolds No.} \approx 10^{-3}$).
- (g) Tentative results show that maximum torque does not occur at an angle of 45° but somewhere between 18° to 24° .
- (h) "Sedimentation of Two Prolate Spheroids in Close Proximity," M. Hnatow, R. Pfeffer and John Happel, Canadian J. of Chem. Engrg., Vol. 47, 1, Feb. 1969, pp. 12-16.

NEW YORK UNIVERSITY, Department of Civil Engineering, School of Engineering and Science, University Heights, New York, N. Y. 10453. Professor James Michalos, Department Chairman.

(7516)

THE EFFECTS OF BENTHAL DEPOSITS ON THE OXYGEN AND NUTRIENT ECONOMY OF NATURAL FLOWING WATERS.

- (b) Federal Water Pollution Control Admin.
(c) Dr. Alan H. Molof.
(d) Experimental; basic and applied research; doctoral thesis.
(e) A study of the oxygen demand and BOD and nutrient release from benthal deposits was conducted under various environmental conditions of sludge depth, temperature, and DO level. All experiments were conducted in continuous flow system.

(7517)

THE EFFECT OF WIND ON ESTUARINE DISPERSION.

- (b) Federal Water Pollution Control Admin.
(c) Dr. Erick R. Gidlund.
(d) Experimental and theoretical; basic and applied research; doctoral thesis.
(e) A physical model study of the effect of wind on the temporal and spatial variations of longitudinal dispersion in a vertically well-mixed estuary.
(h) "The Effect of Wind on Estuarine Dispersion," F. C. Lutz, and E. R. Gidlund, to be published in Proc., Twelfth Conf. on Coastal Engrg., ASCE.

(7518)

NITRIFICATION IN STREAMS.

- (b) National Science Foundation.
(c) Mr. Raul R. Cardenas.
(d) Experimental and theoretical; basic and applied research; doctoral thesis.
(e) A study of the chemical changes resulting from the oxidation of ammonia in an 18 reactor river model under controlled conditions of flow, temperature and mixing.
(h) "Nitrogen Relationships in Streams," R. R. Cardenas and A. H. Molof, to be published in J. Water Poll. Control Fed.

NEW YORK UNIVERSITY, Department of Meteorology and Oceanography, School of Engineering and Science, University Heights, New York, N. Y. 10453. Department Chairman.

(3120)

OFFICE OF NAVAL RESEARCH ATMOSPHERE INTERACTION AND WAVE PROJECT.

- (b) Geophysics Branch, Office of Naval Research, Dept. of the Navy.
(c) Prof. Gerhard Neumann, Prof. Willard J. Pierson,

- Prof. A. D. Kirwan, Jr. and Prof. E. S. Posmentier.
(d) Experimental and theoretical; basic and applied research.
(e) Large-scale oceanographic prediction on numerical integration of the primitive hydrodynamic equations with more realistic boundary conditions.
(g) Detailed surveys of the Tropical Atlantic Ocean circulation have shown that the Equatorial Undercurrent exists throughout the year between about 40°N and the inner part of the Gulf of Guinea. Significant seasonal changes of its velocity and of its temperature-salinity structure are observed and related to seasonal changes of the prevailing wind system and to the difference evaporation-precipitation in the equatorial zone.
(h) "The Equatorial Undercurrent in the Atlantic Ocean," G. Neumann, Proc. Symp. on Oceanogr. and Fisheries Resources of the Trop. Atlantic, pp. 33-34, Publ. UNESCO, 1969, Paris, France.
"Seasonal Salinity Variations in the Upper Strata of the Western Tropical Atlantic Ocean - I. Sea Surface Salinities," G. Neumann, Deep Sea Research, Suppl. to Vol. 16, pp. 165-177, Pergamon Press, 1969.
"Formulation of Constitutive Equations for Large-Scale Turbulent Mixing," A. D. Kirwan, Jr., J. Geophys. Res., Vol. 74, No. 28, 1969.
"Simple Flow of a Fluid Containing Deformable Structures," A. D. Kirwan and N. Newman, Int. J. Engrg. Sci., Vol. 7, pp. 1067-1078, Pergamon Press, 1969.
"A Study of Temperature and Salinity Changes Along a Northern New Jersey Coast," T. Pease, Sci. Rept., N.Y.U., Dept. of Meteor. and Ocean., TR-69-7.
"Measurement of Atmospheric Turbulence a Few Meters Above the Sea Surface with a Three Component Thrust Anemometer," S. Adelfang, Sci. Rept. N.Y.U. Dept. of Meteor. and Ocean., TR-69-3.

(6767)

RADAR SATELLITE OCEANOGRAPHY.

- (b) National Aeronautics and Space Admin., and U.S. Naval Oceanog. Office.
(c) Prof. Willard J. Pierson, Jr.; Asst. Prof. Vincent Cardone.
(d) Experimental and theoretical; basic and applied research.
(e) Development of ways to hindcast waves by spectral techniques on an oceanwide basis. The North Atlantic has been completed, and the North Pacific is nearly completed. Study of ways to use radar scatterometry and altimeter on a spacecraft to determine wave properties at the ocean surface and features of the geoid.
(g) Aircraft surface truth program well under way. Results of Pacific Hindcasting study are being extended to the whole earth and ways to incorporate spacecraft data in improved analyses of the surface wind field over the oceans are under development.
(h) "A Proposed Vector Wave Number Spectrum for the Study of Radar Sea Return," W. J. Pierson, Jr. (to be published).
"Radar Altimetry from a Spacecraft and its Potential Applications to Geodesy," J. A. Greenwood, A. Nathan, G. Neumann, W. J. Pierson, F. C. Jackson and T. E. Pease. Remote Sensing of Environment 1 (1969) 59-70.
"Oceanographic Applications of Radar Altimetry from a Spacecraft," J. A. Greenwood, A. Nathan, G. Neumann, W. J. Pierson, J. C. Jackson and T. E. Pease, Remote Sensing of Environment 1 (1969) 71-80.
"Specification of the Wind Distribution in the Marine Boundary Layer for Wave Forecasting,"

NIELSEN ENGINEERING AND RESEARCH, INCORPORATED, 850 Maude Avenue, Mountain View, California 94040. Dr. Jack N. Nielsen, President.

(7528)

THEORETICAL STUDY OF VORTEX SHEDDING FROM BODIES OF REVOLUTION UNDERGOING CONING MOTION.

(b) Ames Research Center, NASA.

(c) S. B. Spangler.

(d) Theoretical; applied research.

The purpose of the investigation is to develop methods for predicting the normal and side-force distribution on slender bodies undergoing a coning motion at a sufficiently high angle of attack that flow separation and asymmetric vortex formation occur over the leeward side of the body.

(f) Completed.

(g) Theoretical results agreed substantially with measured values of vortex positions and vortex-induced loadings on an ogive-cylinder. The theory demonstrates the asymmetry in vortex strength and position, and appears capable of explaining the development of the steady asymmetric vortex pattern on bodies at high angle of attack with no coning motion.

(h) "Theoretical Study of Vortex Shedding from Bodies of Revolution Undergoing Coning Motion," G. D. Kuhn, S. B. Spangler, and J. N. Nielsen, NASA CR-1448, Oct. 1969.

NORTH AMERICAN ROCKWELL CORPORATION, ROCKETDYNE DIVISION, Advanced Systems, 6633 Canoga Avenue, Canoga Park, California 91304. S. F. Iacobellis, Manager.

(7604)

ANALYSIS OF TWO-PHASE FLOW IN LH₂ PUMPS FOR O₂/H₂ ROCKET ENGINES.

(b) National Aeronautics and Space Admin., MSFC, Huntsville, Ala. (part of program entitled "Thermodynamic Improvements in Liquid Hydrogen Turbo-pumps," contract NAS8-20324).

(c) W. R. Bissell.

(d) Theoretical; applied research.

(e) The two-phase pumping capability of liquid hydrogen pump was analyzed and hydrodynamic design criteria for improving two-phase pump performance were established.

(f) Completed.

(g) An analysis was made to determine the two-phase pumping capability of liquid hydrogen pumps and to establish hydrodynamic design criteria to improve two-phase pump performance. The analysis includes equilibrium and constant-quality flow processes and considers acoustic effects, compressible flow, and cavitation. Both cavitation and two-phase hydrogen experimental pump data were used in the analysis. Present hydrogen pumps can operate at approximately 30 percent vapor-volume fraction. Results from analysis show that this capability can be doubled by utilizing proper pump configuration and hydrodynamic design. Vehicle tank pressure requirements for zero pump NFPH, chilldown time, and chilldown propellant requirements were predicted as a function of inlet vapor-volume fraction.

(h) "An Analysis of Two-Phase Flow in LH₂ Pumps for O₂/H₂ Rocket Engines," W. R. Bissell, G. S. Wong, and T. W. Winstead, AIAA Paper No. 69-549, pre-

(7605)

THE TRANSIENT PERFORMANCE OF A HYDRAULIC-TURBINE-DRIVEN INDUCER: COMPUTER PREDICTIONS AND TEST VERIFICATION.

(b) National Aeronautics and Space Admin., Lewis Research Center, Cleveland, Ohio.

(c) J. A. King and E. C. Farrel.

(d) Theoretical and experimental; applied research.

(e) The purpose of the contract was the development of a computer program that would predict the transient performance of a low-speed inducer driven by a partial-flow, hydraulic turbine. Two programs, an analog and a digital were developed that will do this. To check the accuracy of the programs, an inducer-turbine was designed, fabricated, and tested.

(f) Completed.

(g) Analog and digital computer programs were developed to predict the transient performance of a low speed, hydraulic turbine driven inducer. An inducer-turbine unit was designed, fabricated, and tested, and it verified the validity of the computer models.

(h) "Final Report - The Transient Performance of a Hydraulic-Turbine-Driven Inducer: Computer Predictions and Test Verification," J. A. King and E. C. Farrel, NASA CR-72518 and R-7747, Feb. 1969.

(7606)

LOW-SPEED INDUCER FOR A ROCKET ENGINE FEED SYSTEM.

(b) National Aeronautics and Space Admin., Lewis Research Center, Cleveland, Ohio.

(c) J. A. King.

(d) Theoretical applied research.

(e) The purpose of this program is to conduct an analytical investigation for the use of low-speed inducers in a rocket engine feed system. Analytical low-speed inducer performance data will be developed to evaluate the potential of eliminating propellant tank pressurization and avoiding the resonant interaction of oscillations in the feed system with the vehicle structure.

(g) The analytical investigation is being conducted.

(7607)

DESIGN OF INDUCERS FOR TWO-PHASE OPERATION.

(b) George C. Marshall Space Flight Center, National Aeronautics and Space Admin., Huntsville, Ala.

(c) J. A. King.

(d) Theoretical and experimental; applied research.

(e) The purpose of this program is to establish the design criteria for pump inducers that will have improved pumping characteristics while pumping two-phase fluid.

A hydrodynamic and thermodynamic design analysis of two-phase inducers will be conducted. An inducer will be designed, fabricated and tested in liquid hydrogen. The test data obtained will then be analyzed to obtain a correlation between the mathematical model and test results. This correlation will be used to establish design criteria and to make design recommendations for two-phase hydrogen inducers.

(g) The hydrodynamic and thermodynamic analysis of the two-phase inducer have been completed. The inducer has been designed and fabricated and is presently being readied for LH₂ testing.

(7608)

IMPELLER CLEARANCE EFFECTS.

(b) National Aeronautics and Space Admin., Lewis Research Center, Cleveland, Ohio.

- (c) R. K. Hoshide.
- (d) Theoretical and experimental; applied research.
- (e) The purpose of this program is to evaluate the effects of centrifugal pump impeller clearances on rocket engine pump performance and cost. The program consists of 1) a literature survey, 2) an analytical model formulation to predict the effects of impeller tip clearance on performance, 3) a clearance and cost analysis, 4) design and fabrication of the test assembly and 5) testing of a semi-open impeller at various clearances and comparing the actual and analytically predicted changes in pump performances.
- (g) The literature survey, and the clearance and cost analysis have been completed. The performance model formulation is being completed with an analytical relationship expressing a change in impeller head coefficient due to a change in tip clearance being developed. The design and fabrication of the test assembly is being completed.

NORTH AMERICAN ROCKWELL CORPORATION, SPACE DIVISION,
Department of Structural Systems and Mechanisms,
 12214 Lakewood Boulevard, Downey, California 90241.
 S. M. Treman, Department Director.

(7529)

HYDROELASTIC ANALYSIS OF AXISYMMETRIC SYSTEMS BY A FINITE ELEMENT METHOD.

- (b) National Aeronautics and Space Admin.
- (c) B. H. Ujihara and R. J. Guyan, Technical Staff, Dept. 191-334.
- (d) Applied research.
- (e) The hydroelastic behavior of axisymmetric systems is analyzed by a finite element approach. The fluid mass matrix is determined for potential flow by a source sheet singularity approach. Description of the elastic container is by the direct stiffness method using a conical frustum element. Fluid incompressibility, shell mass, ullage pressure and liquid free surface effects are included. Primary application to date has been determination of the vibrational behavior of the S-II aft LOX bulkhead for incorporation in a POGO stability analysis model.
- (g) Experimental verification of analytical model has been achieved by vibration testing of actual hardware.
- (h) "Hydroelastic Analysis of Axisymmetric Systems by a Finite Element Method," R. J. Guyan, B. H. Ujihara and P. W. Welch, Proc. Second Conf. on Matrix Methods in Structural Mechanics, AFFDL-TR-68-150. (Dec. 1969) p. 1165-1203.

NORTH CAROLINA STATE UNIVERSITY AT RALEIGH, Department of Engineering Research, Raleigh, North Carolina 27607. Dr. R. W. Cummings, Administrative Dean for Research, N. W. Conner, Assistant Dean.

(6259)

DIFFUSION AND DISPERSION IN POROUS MEDIA - SALT WATER MOUNDS IN COASTAL AQUIFERS.

- (b) Office of Water Resources Research, Dept. of the Interior.
- (c) Prof. Abdel-Aziz I. Kashef.
- (d) Theoretical and experimental.
- (e) Study of the location of the interface of salt water mounds in coastal aquifer considering the effects of natural flow and water well pumping. The flow is considered steady in the theoretical analysis. The unsteady flow is only considered

in the experimental study using a Hele-Shaw model for two-dimensional flow.

- (f) Completed.
- (g) Formulas for the interface are developed in addition to a procedure by which the effect of a group of wells can be determined.
- (h) "Diffusion and Dispersion in Porous Media - Salt Water Mounds In Coastal Aquifers," A. I. Kashef, Water Resources Research Inst., Univ. of North Carolina, Rept. No. 11, pp. 1-258, Sept. 1968. "Fresh-Salt Water Interface In Coastal Ground-Water Basins," A. I. Kashef, Mem. Intl. Assoc. Hydrogeologists, Congr. of Istanbul, Vol. VIII, pp. 369-375, 1968. "Two-Dimensional Gravity Flow Systems of Finite Lengths," A. I. Kashef and D. McDonald, Proc. Natl. Symp. on Ground-Water Hydrology, Amer. Water Resources Assoc., Series No. 4, pp. 214-234, November 1967. "Salt Water Intrusion in Coastal Well Fields," A. I. Kashef, Proc. Natl. Symp. on Ground-Water Hydrology, Amer. Water Resources Assoc., Series No. 4, pp. 235-258.

(7530)

GROUND-WATER MOVEMENT TOWARD ARTIFICIAL CUTS.

- (c) Prof. Abdel-Aziz I. Kashef.
- (d) Theoretical.
- (e) The developed drawdowns due to artificial cuts under the condition of saturated steady flow are theoretically studied. Procedures are given for the cases of highway cuts and open channels.
- (f) Completed.
- (g) The proposed method is simpler in its application than some previous analogous solutions in which the free surface is the main concern. The presented solution is complete in finding the other phases of such problems.
- (h) "Ground-Water Movement Toward Artificial Cuts," A. I. Kashef, Water Resources Res., Vol. 5, No. 5, pp. 1032-1040, Oct. 1969. "Seepage Towards Highway Cuts," A. I. Kashef, Proc. Amer. Soc. Civil Engrg., Transport. Engrg. J., Vol. 95, No. TE4, pp. 667-680, Nov. 1969.

(7531)

INTERFERENCE BETWEEN GRAVITY WELLS.

- (c) Prof. Abdel-Aziz I. Kashef.
- (d) Theoretical.
- (e) Stress was previously made on the study of group action of artesian wells. Gravity wells are studied by proposing a restricted superposition procedure. Steady as well as transient states of flow are analyzed.
- (f) Completed.
- (g) Unified well equations are proposed for use in either artesian or gravity wells under either the steady or transient states of flow. The procedure is an essential step in studying the well fields management.
- (h) "Interference between Gravity Wells-Steady State Flow," A. I. Kashef, presented at Fifth Amer. Water Resources Conf. San Antonio, Texas, Oct. 1969; publication is underway. "Multiple Gravity Wells under Transient States of Flow," A. I. Kashef, presented at Fifth Amer. Water Resources Conf., San Antonio, Texas, Oct. 1969; publication is underway.

UNIVERSITY OF NORTH CAROLINA, School of Public Health,
Department of Environmental Sciences and Engineering,
 Chapel Hill, North Carolina 27514. Dr. Daniel A. Okun, Department Chairman.

(7532)

TRANSPORT MECHANISMS IN WATER FILTRATION.

- (b) Bureau of Water Hygiene, Dept. of Health, Education, and Welfare.
- (c) Prof. Charles R. O'Melia.
- (d) Theoretical and experimental.
- (e) A model is developed for the mass transport of particles suspended in water to the surfaces within a packed bed of porous media during laminar flow. Experimental testing of the model is provided.
- (g) The theoretical model accounts for mass transport by diffusion, interception, and settling in laminar flow. Both the theoretical model and the experimental results indicate that the most significant parameter in such systems is the size of the suspended particles. Small particles (less than one micron in size) are readily transported to the media surface by diffusion; large particles (greater than one micron in size) are effectively transported by sedimentation and interception.
- (h) "Particle Transport in Aqueous Flow Through Porous Media," K. M. Yao and C. R. O'Melia, ASCE Hydraulic Conf. 1968, available as ESE Publ. No. 210, Dept. of Environmental Sciences and Engrg., Univ. of North Carolina, Chapel Hill, N.C. 27514.

(7533)

IMPROVED DRINKING WATER QUALITY THROUGH DUAL SYSTEMS.

- (b) U. S. Public Health Service.
- (d) Field; applied research, design, thesis.
- (e) Determination of those circumstances in which a dual water supply system (one part supplying "pure" or "innocent" water from protected sources for potable use, the other supplying reclaimed or "repellent" water for other uses) would be feasible.
- (h) "Alternatives in Water Supply," Daniel A. Okun, J. Amer. Water Works Assoc., Vol. 61, No. 5, pp. 215-221, May 1970.

(7534)

WATER QUALITY MANAGEMENT OF IMPOUNDMENTS.

- (b) Office of Water Resources Research, U.S. Dept. of Interior through the Water Resources Research Inst., Univ. of North Carolina.
- (c) Dr. Charles M. Weiss.
- (d) Field investigation.
- (e) Destratification of an impoundment by vertical circulation generated by air lift will be used to examine consequent water quality changes.

(118W)

COMPUTER SIMULATION OF AQUIFERS OF COASTAL PLAIN OF NORTH CAROLINA.

- (c) J. K. Sherwani.
- For summary, see Water Resources Research Catalog, Vol. 4, No. 2.0821, 2.0822.

NORTH DAKOTA STATE UNIVERSITY OF AGRICULTURE AND APPLIED SCIENCE, Agricultural Engineering Department, Fargo, North Dakota 58102. Professor W. J. Promersberger, Department Chairman.

(034W)

A FEASIBILITY STUDY OF A LIVESTOCK WASTE DISPOSAL SYSTEM INVOLVING REUSE OF WATER.

(Project terminated December 31, 1968.)
Summarized in Water Resources Research Catalog.

(035W)

A PHYSICAL AND ECONOMIC ANALYSIS OF ALTERNATE IRRIGA-

GATION METHODS IN A SUB-HUMID CLIMATE.

Summarized in Water Resources Research Catalog.

(5471)

DITCH LININGS AND UNDERGROUND PIPE FOR IRRIGATION SYSTEMS.

- (b) Joint project with Carrington Irrigation Branch Station.
- (c) Superintendent H. M. Olson, Carrington Irrigation Branch Station, Carrington, North Dakota.
- (d) Field investigation, applied research, design, development, for thesis.
- (e) The project involved placing various lengths of buried concrete, plastic, concrete asbestos and aluminum pipe for conveying irrigation water on the farm. A concrete lined surface ditch was also used. Such factors as cost of installation, stability of pipe, depth of overburden, hydraulic characteristics, joints and fittings, annual maintenance cost, and life of various types of pipe are to be observed.
- (g) Pipe is installed but no data has been accumulated.

(6114)

EVALUATION OF EXTENSIVE IRRIGATION.

- (c) Dr. E. C. Stegman.
- (d) Experimental; applied research.
- (e) Water budget management schemes for multiple field operation of center pivot sprinkler systems are being evaluated. Water application efficiencies are also being studied.
- (g) An earlier study under this project revealed that distribution efficiencies of 70 per cent or more were achieved with a center pivot sprinkler system operating in wind velocities of up to 16 mph.

NORTHERN MICHIGAN UNIVERSITY, School of Arts and Sciences, Department of Geography, Earth Science and Conservation, Marquette, Michigan 49855. Dr. Robert T. Wagner, Department Head.

(6053)

DRIFT BOTTLE STUDY OF THE SURFACE CURRENTS OF LAKE SUPERIOR.

- (c) Dr. John D. Hughes, Asst. Prof.
- (d) Field investigation; basic research.
- (e) It is the purpose of this study to determine the surface current pattern of Lake Superior as it exists during each of the four seasons of the year.
- (g) 617 returns from 4845 drifters released (Dec. 1969). One preliminary qualitative paper published in Michigan Academician, winter 1970.

NORTH STAR RESEARCH AND DEVELOPMENT INSTITUTE, 3100 38th Ave. South, Minneapolis, Minnesota 55406. R. Q. Wilson, Vice President.

(6089)

DEVELOPMENT OF A FLUID CONCENTRATED DISPERSION OF A WATER SOLUBLE POLYMER CAPABLE OF REDUCING THE FRICTION OF WATER UNDER TURBULENT CONDITIONS.

- (b) Naval Ship Research and Development Ctr.
- (c) Mr. Roy E. Larson; Director of Research, Engineering.
- (d) Experimental; basic research.
- (e) The research efforts are directed toward the development of a method for deploying water-soluble polymers around ship hulls to reduce the effects of water turbulence. Friction-reducing

polymers are dispersed in a nonsolvent carrier liquid. The polymer particles are not dissolved, but remain suspended as discrete particles. Fluid slurries containing up to 50 percent of friction-reducing polymers have been utilized.

- (f) Completed.
- (g) Dispersions (slurries) of up to 45 percent water-soluble polymers in nonsolvent carriers were effective for reducing drag in turbulent flowing water streams. Separan or polyox, in polypropylene glycol, gave about 20 percent friction reduction in mixing times less than 0.3 second and reductions of over 60 percent in 1.5 seconds in a 0.26-inch ID tube. In a 10-inch pipe, friction reductions of 30 percent were obtained. Decreasing the water temperature from 40° F to 30° F and adding 3.5 percent salt to the water had only minor effects on friction reduction. The optimum concentrations of polymer in the water stream were approximately 80 ppm. Dispersants of polymer have been held 18 months without settling or dissolving.
- (h) "Development of a Fluid Concentrated Dispersion of a Water-Soluble Polymer Capable of Reducing the Friction of Water Under Turbulent Conditions," R. Forester and P. Francis, Final Report, Contract Nonr 4827(00), Oct. 1966, David Taylor Model Basin Contract Research Admin., Hydromechanical Lab. "Development of a Fluid Concentrated Dispersion of a Water-Soluble Polymer Capable of Reducing the Friction of Water Under Turbulent Conditions," R. Forester, L. Rozelle and R. Larson, Final Report, Contract Nonr 4827(00), Jan. 1968, Naval Ship Res. and Dev. Ctr. "Effects of Polymer Addition on Friction in a 10-in.-Diam Pipe," R. Forester and R. E. Larson, J. Hydronautics, Vol. 3, No. 1, Jan. 1969, pp. 59-62.

(7535)
STUDY OF FRICTION REDUCTION MECHANISMS USING AN INTERFEROMETRIC TECHNIQUE.

- (c) Mr. Roy E. Larson.
- (d) Experimental basic research.
- (e) Many investigators have reported significant pressure-drop reductions in various water-flow systems, caused by the addition of small amounts of high-molecular-weight polymers. It is thought that viscoelastic behavior or thickening of the laminar sublayer brings about the reductions in friction that have been measured. The objective of the program is to use an interferometric method to determine if viscoelastic effects are occurring in the laminar sublayer. If these effects are present, the interferometer should provide visual indication of their presence and allow determination of their magnitude. Successful completion of this program will provide a significant contribution toward obtaining an understanding of the mechanisms responsible for friction reduction in dilute polymer solutions.

NORTHWESTERN UNIVERSITY, The Technological Institute,
Evanston, Illinois 60201. Dr. Walter S. Owen, Dean of Institute.

- (3799)
FORCES ON SUBMERGED BODIES IN UNSTEADY MOTION.
- (c) Prof. W. S. Hamilton or Prof. L. F. Mockros, Dept. of Civil Engrg.
- (d) Theoretical and experimental; basic research; M.S. and Ph.D. theses.
- (e) Investigation of the forces on solid bodies ac-

celerating along a rectilinear path through incompressible viscous fluids. The investigation includes (1) experiments that will be compared with numerical evaluation of theoretical linear solutions, (2) experiments on the general case of large motions, and (3) a study of the effect of the velocity pattern on added mass.

- (g) The limit of validity of the Stokes flow solution for an accelerating falling sphere has been delineated. The Stokes linearized equations of motion were used to obtain the flow field generated by and the drag on prolate and oblate spheroids executing translatory oscillations. The Stokes flow drag is also calculated on spheroids moving with a general acceleration parallel to their axes of symmetry. The theory was used to calculate the dynamic behavior of underwater structures of spheroidal shape. The added mass coefficient for four- and six-inch spheres released from rest in and with constant velocity through water has been determined experimentally to be 0.5.
- (h) "Validity of Stokes Theory for Accelerating Spheres," L. F. Mockros and R. Y. S. Lai, J. Engrg. Mechanics Div. ASCE, Vol. 95, 629-640, 1969. "Oscillatory Behavior of Submerged Structures," Proc. Civil Engrg. in the Oceans, II, 1969.

(5472)

DYNAMICS OF THE CIRCULATION IN THE GREAT LAKES.

- (c) Assoc. Prof. G. E. Birchfield, Dept. of Engrg. Sciences.
- (d) Theoretical study; primarily basic research.
- (e) Develop mathematical models of wind generated motions in large lakes. Use with recent observational studies to construct model of general circulation.
- (g) Some simple analytical models completed. Some observational studies completed.
- (h) "Response of a Circular Model of a Great Lake to a Suddenly Imposed Wind Stress," G. E. Birchfield, J. Geo. Res. Vol. 74, No. 23, 5547-5554. "Statistical Analysis of Currents at Two Near-by Stations in Lake Michigan, Summer 1967," Proc. Conf. Great Lakes Res., Univ. of Wisconsin-Milwaukee, 1968.

(5474)

EXTRACORPOREAL CIRCULATION.

- (b) National Institute of General Medical Sciences.
- (c) Prof. Lytle F. Mockros.
- (d) Theoretical and experimental; basic and applied research; M.S. thesis; Ph.D. dissertation.
- (e) Investigation of the geometry and fluid dynamics favorable to the circulation of blood outside the animal body. Purpose is to obtain design criteria for heart lung machines.
- (g) Related rate of red cell lysis to mechanical energy dissipation. Oxygen transfer to and carbon dioxide removal from blood flowing in gas-permeable conduits has been investigated theoretically and experimentally. Investigations include studies of effects of laminar convection in coiled tubes and curved channels.
- (h) "Gas Transfer to Blood Flowing in Coiled Circular Tubes," M. H. Weissman and L. F. Mockros, J. Engrg. Mechanics Div. ASCE, Vol. 94, 857-872, 1968. "Hemolytic Effects of Energy Dissipation in Flowing Blood," M. Bluestein and L. F. Mockros, Medical and Biological Engrg., Vol. 7, 1-16, 1969. "Oxygen and Carbon Dioxide Transfer in Membrane Oxygenators," M. H. Weissman and L. F. Mockros, Medical and Biological Engrg., Vol. 7, 169-184, 1969.

"Hydrodynamic Characteristics of Prosthetic Aortic Valves," A. H. Pettifor and L. F. Mockros, The Annals of Thoracic Surgery, Vol. 9, 122-135, 1970.

(7536)

ANALYSIS OF CARDIAC ASSIST DEVICES.

- (b) National Institute of General Medical Sciences.
- (c) Prof. Lyle F. Mockros.
- (d) Theoretical and experimental; basic and applied research; Ph.D. dissertation.
- (e) The arterial system from the heart to the femoral arteries is mathematically modeled. The method of characteristics is used for solving the equations. The model is used to study the physiologic characteristics of the arterial system and to study the effectiveness of various proposed schemes for assisting a failing heart. Qualitative experiments are carried out using dogs as the test animal.
- (g) Pressure wave shape, input and output impedance, wave travel and apparent wave velocity compare favorably with experiments by others. Comparisons of four methods of cardiac assistance in terms of their effects on mean systolic pressure, mean diastolic pressure, aortic end-diastolic pressure, and cardiac pressure-volume work, show intraortic balloon performance to be sensitive to size, deflation timing and stiffness of aorta.

(7537)

ROLE OF THERMAL CONVECTION CURRENTS IN SOLIDIFICATION.

- (c) Richard S. Tankin, Assoc. Prof., Dept. of Mech. Engrg. and Astronautical Sciences.
- (d) Experimental; basic research; Ph.D. thesis.
- (e) In freezing of water it is expected that stationary cellular pattern is established in the water. This will lead to striated (or spotted) pattern of ice formation on a uniformly cooled surface.
- (g) Equipment is now being set up to carry out experiments.

(7538)

GAS FLOW THROUGH SAND.

- (c) Prof. W. S. Hamilton, Dept. of Civil Engrg.
- (d) Theoretical, basic research for M.S. and Ph.D. theses.
- (e) Calculating unsteady gas flow through a porous medium is a difficult matter and simplifying assumptions such as a constant temperature process often are used. The purpose of this work is to solve more exact equations numerically and compare the results with those obtained when approximations are made.
- (g) The pseudo-steady state pressure profiles assumed by Muskat in the case of constant mass flow from a well are in error by less than ten percent.
- (h) "Evaluation of a Pseudo-Steady State Approximation for Unsteady Flow from a Gas Well," Brent Taylor, M.S. Thesis, June 1968.

(7539)

FLOW OF SLUDGE IN PIPES.

- (c) Prof. W. S. Hamilton, Dept. of Civil Engrg.
- (d) Theoretical, applied research for Ph.D. thesis.
- (e) A rational explanation and statement of the effect of flexible elongated particles on turbulence, velocity profiles and friction in pipes is sought.

UNIVERSITY OF NOTRE DAME, Department of Aerospace and Mechanical Engineering, Notre Dame, Indiana 46556.
Professor K. T. Yang, Department Chairman.

(7540)

STUDIES OF NUMERICAL MODELS OF TURBULENT FUNCTIONS.

- (c) Prof. B. Betchov.
- (d) Theoretical, basic research.
- (e) The signal received from a hot-wire anemometer in a turbulent flow has correlations of odd orders, resulting from phase relations. Experiments done elsewhere have revealed simple relations between correlations of order 3, 5 and 7. This study concerns with numerical computations based on simple random nonlinear models to determine generality of these odd-order correlations.

(7541)

EXPERIMENTS ON STRONG TURBULENCE.

- (c) Prof. R. Betchov.
- (d) Experimental, basic research.
- (e) A turbulence box has been built in our laboratory which is capable of generating one cubic meter of strong turbulence in air under conditions that greatly facilitate the measurements by hot-wire or other techniques. Correlations of order two to eight will be measured to determine the existence of simple relations. Measurements will also be made to examine the dynamics of large vortices as well as to study the intermittency of the turbulence and its effect on diffusion. The student will first become familiar with hot-wire anemometry, and then will have the opportunity to work with this unique facility in turbulence research.

(7542)

DESIGN OF A METEOROLOGICAL WIND TUNNEL FOR ATMOSPHERIC DIFFUSION STUDIES.

- (c) Prof. A. A. Szewczyk.
- (d) Experimental, basic research.
- (e) It has been demonstrated that wind profiles in the surface layer near the ground can be successfully simulated in a wind tunnel under specific conditions. A project has been initiated in our laboratory to design and build such a meteorological wind tunnel with capabilities to simulate ground heating, temperature inversion, and ground or elevated diffusion sources, as well as auxiliary instrumentation and sampling devices.

(7543)

NUMERICAL EXPERIMENTS IN FLUID MECHANICS.

- (c) Prof. A. A. Szewczyk.
- (d) Theoretical, basic research.
- (e) Recent studies here at the University of Notre Dame concerning numerical integration of the complete Navier-Stokes equation for flow about a circular cylinder have provided a confidence in the numerical technique. This two-dimensional technique is now extended to an axisymmetric problem of a rotating sphere in an infinite fluid.

(7544)

FLAT PLATE FLOW UNDER SUDDEN SUCTION OR BLOWING.

- (c) Assoc. Prof. V. W. Nee.
- (d) Theoretical, basic research.
- (e) A flat plate in a constant moving stream is suddenly turned into one with uniformly distributed suction or blowing. For a semi-infinite plate, the Blasius profile in the boundary layer will in time change into the asymptotic suction profile. For an infinite plate, the error function profile will develop into one with suction.

(7545)

LAMINAR AND TURBULENT FREE CONVECTION IN A DENSITY STRATIFIED ENVIRONMENT.

- (b) Office of Naval Research.
- (c) Assoc. Prof. S. T. McComas.

- (d) Experimental, basic research.
- (e) An environmental tank (30" dia. and 60" high) has been fabricated to permit measurements on the effect of density stratification in a fluid environment on laminar and turbulent free convection along heated surfaces. Liquid solutions and gas mixtures up to 200 psia can be accommodated. Use is made of a six-inch Mach-Zehnder interferometer for mapping temperature fields in the vicinity of the heated surfaces.

(7546)

STUDIES RELATED TO UNDERSEA JET PROPULSION.

- (b) Office of Naval Research.
- (c) Prof. J. L. Novotny and Prof. K. T. Yang.
- (d) Experimental, basic research.
- (e) To design under-water jet propulsion systems, the basic behavior of under-water jets has to be understood. This study is primarily concerned with the experimental investigation of the pressure and temperature fields surrounding a supersonic steam jet discharging into a large volume of water. Also included in this study is the design of a scale model of a submersible with a jet propulsion system. This scale model will be tested under water.

(7547)

SUBSONIC AXISYMMETRIC TURBULENT WAKE.

- (b) NASA.
- (c) Prof. T. J. Mueller.
- (d) Experimental, basic research.
- (e) Detailed measurements will be obtained in the subsonic wind tunnels using a hot-wire anemometer and pitot probes. Emphasis will be placed on the influence of Reynolds number and on the phenomenon of separation from the model and recompression or wake closure at the downstream end of the wake.

(7548)

AXISYMMETRIC AND NON-AXISYMMETRIC ALTITUDE COMPENSATING PROPLUSIVE NOZZLES.

- (b) NASA.
- (c) Prof. T. J. Mueller.
- (d) Experimental, applied research.
- (e) An experimental study of the nozzle flow field and base drag for several space shuttle afterbody configurations are studied. Thrust and base pressure distribution are measured and flow field examined using various optical techniques.

UNIVERSITY OF NOTRE DAME, Department of Civil Engineering, Notre Dame, Indiana 46556. Dr. Don A. Linger, Department Chairman.

(7549)

BIOGEOCHEMICAL MODELING OF EUTROPHIC LAKES.

- (b) Federal Water Pollution Control Admin.
- (c) W. F. Echelberger, Jr.; M. W. Tenney; P. C. Singer and F. H. Verhoff.
- (d) Theoretical, experimental and field investigation; M.S. and Ph.D. theses.
- (e) The purpose of this project is the development of a modeling concept of the ecological system in eutrophic lakes such that the dynamics of this system in a changing environment can be accurately predicted and controlled. Computer techniques are utilized in an attempt to develop a lake model which can be used to predict the water quality of a lake in future years as a result of pollution and/or to establish priorities for the selection of methods of external manipulation of eutrophic lakes (e.g., pollution abatement, bot-

tom sealing, dilution with nutrient free water, etc.) which will most significantly enhance lake recovery.

- (g) A mathematical simulation (time discrete linear model) of the biogeochemical exchanges within an eutrophic lake system has been developed; and its use in the synthesizing of the eutrophication history of a specific test lake, as the result of pollution inputs, has been demonstrated. Based on this result it is felt that this model closely approximates the biogeochemical processes in the test lake and can be used to predict future water quality change as a result of certain perturbations on the lake system. Current and planned studies are concerned with a non-linear modeling concept for a more realistic description of the internal lake processes involved and hence better predictive capabilities.
- (h) "Documentation, Mathematical Modeling and External Manipulation of an Eutrophic Lake," M. A. Sweet, M.S. thesis, Feb. 1969.
"Biogeochemical Modeling of Eutrophic Lakes," W. F. Echelberger, Jr., M. W. Tenney, P. C. Singer, F. H. Verhoff and W. A. Garvey; Proc. Workshop on Eutrophication Modeling, Univ. of Florida, in press 1970.
"Biogeochemical Modeling of an Eutrophic Lake for Water Quality Improvement," Proc. Fifth Intl. Conf. on Water Pollution Res., San Francisco, in press 1970.

(7550)

CHEMICAL CONDITIONING OF BIOLOGICAL SLUDGES TO ENHANCE PIPELINE TRANSPORT.

- (b) National Institutes of Health.
- (c) W. F. Echelberger, Jr. and J. E. Lindell.
- (d) Theoretical, experimental and field investigation; M.S. and Ph.D. theses.
- (e) The principal objective in this study is to determine if certain chemical additives, such as synthetic organic polyelectrolytes, can be used to enhance the long distance pipeline transport of biological sludges from wastewater treatment processes. The total scope of the study includes theoretical delineation of the fundamental hydraulic mechanisms, laboratory pipeline studies followed by field evaluation of laboratory results.
- (g) It has been found that certain polyelectrolytes do enhance the pipeline movement of biological sludges and also assist in dewatering these sludges following discharge from the pipe. The enhancement mechanism appears to be a frictional resistance reduction due to the orientation of the polyelectrolyte additives at the sludge - pipeline interior wall interface.
- (h) "Chemical Conditioning of Biological Sludges to Enhance Pipeline Transport," R. C. Hansen, M.S. thesis, 1970.

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER, Department of Agricultural Engineering, Wooster, Ohio 44691. Dr. R. E. Stewart, Department Chairman.

(036W)

FLOW OF COLLOIDAL SUSPENSIONS IN POROUS MEDIA.

- (c) Prof. R. Bruce Curry.
- For summary, see Water Resources Research Catalog, Vol. 4, 2, 0871.

(119W)

SURFACE AND SUBSURFACE DRAINAGE FOR SLOWLY PERMEABLE SOILS.

- (c) Dr. G. O. Schwab.

For summary, see Water Resources Research Catalog, Vol. 4, 4.0192.

(120W)

IRRIGATION REQUIREMENTS OF FIELD AND HORTICULTURAL CROPS.

(c) Prof. R. Bruce Curry.

For summary, see Water Resources Research Catalog, Vol. 4, 2.0872.

(121W)

HYDROLOGICAL CHARACTERIZATION OF SMALL WATERSHEDS.

(c) Prof. R. Bruce Curry.

For summary, see Water Resources Research Catalog, Vol. 4, 4.0197.

OHIO STATE UNIVERSITY, Department of Agronomy,
Columbus, Ohio 43210. Professor George S. Taylor.

(5176)

SOIL CHARACTERISTICS AND SUBSURFACE DRAINAGE.

(b) Ohio Agricultural Experiment Station.

(d) Experimental investigation, applied research.

(e) Numerical analysis solutions of soil moisture flow problems in subsurface drainage are made with digital computers. Steady-state and transient analyses are studied for various parameters of size, depth, and spacing of tile and ditch drains and of soil hydraulic conductivity. Hillside seepage problems are also evaluated. Field evaluations of hydraulic conductivity are made with the aid of lysimeter-type installations. The principal objective is to interrelate the above factors in rational design of subsurface drainage systems.

(g) Characteristics of water flow into tile drains have been studied for layered soils. An analysis of hillside seepage into open ditches was made. Agreement between analytical and numerical analysis techniques was established.

(h) "Computer Solutions for the Drainage of Sloping Land," J. N. Luthin and G. S. Taylor, Trans. Amer. Soc. Agric. Engr., Vol. 9, No. 4, pp. 546-549, 1966.

"Field Evaluation of Tile Drain Filters in Humid Region Soil," G. S. Taylor and T. Goins, Ohio Agric. Res. and Dev. Ctr. Res. Cir. 154, 1967.

OHIO STATE UNIVERSITY, Department of Chemical Engineering,
Columbus, Ohio 43210. Aldrich Syverson,
Department Chairman.

(7551)

A VISUAL INVESTIGATION OF THE LAMINAR-TURBULENT TRANSITION.

(c) Robert S. Brodkey or Harry C. Hershey.

(d) Experimental; basic; doctoral theses.

(e) An experimental study into the basic mechanism of the entire laminar turbulent transition for both boundary layer and pipe flow, to elucidate clearly the steps that occur in the transition from laminar to turbulent flow and to clarify which, if any, theories apply for the various steps known to exist.

(g) Equipment under construction.

(h) "A Visual Study of the Wall Region in Turbulent Pipe Flow," R. S. Brodkey and E. R. Corino, J. Fluid Mech., 37, (1969).

(7552)

TURBULENT MOTION AND MIXING.

(b) Natl. Science Foundation.

(c) Robert S. Brodkey.

(d) Experimental and theoretical; basic; doctoral thesis.

(e) An experimental and theoretical approach to the basic interactions of turbulence and the mixing of a scalar quantity such as mass. Mixing of heat or mass in a turbulent field can in principle be determined from a knowledge of the existing turbulence in the system and the molecular properties of the material being mixed. The object is to accomplish this prediction.

(g) A number of papers have been published by the investigators of this work. We have been able to accomplish the prediction for pipe flow and are now working on a reactor configuration. Furthermore, we have been successful in extending the analysis to the prediction of the effect on chemical kinetics.

(h) "The Scalar Spectra in the Viscous-Convective Subrange," R. S. Brodkey and J. O. Nye, J. Fluid Mech., 29, 151 (1969). This paper contains references to older publications.

(7553)

A VISUAL INVESTIGATION OF DRAG REDUCTION AND DRAG REDUCTION IN NONAQUEOUS SOAP SOLUTIONS.

(b) Natl. Science Foundation.

(c) Harry C. Hershey.

(d) Experimental; basic.

(e) An experimental study into the basic mechanism of drag reduction in pipe flow using high molecular weight polymer or soap solutions and into the laminar and turbulent behavior of soap solutions. Flow in the wall region of a drag reducing fluid is being compared visually to the flow of a pure solvent. The technique involves high speed photography of colloidal-size particles. A parallel investigation is studying the laminar and turbulent behavior of various aluminum soaps in nonaqueous solvents.

OHIO STATE UNIVERSITY, Water Resources Center,
Columbus, Ohio 43210. Professor George S. Taylor.

(6734)

WELL DRAWDOWN IN UNCONFINED AQUIFERS UNDER NON-STEADY CONDITIONS.

(b) Office of Water Resources Research, U.S. Dept. of Interior.

(c) Prof. George S. Taylor, Dept. of Agronomy, Ohio State Univ.

(d) Experimental investigations; applied research.

(e) This study is a numerical analysis study of drawdown around wells in unconfined porous media for transient conditions. The simultaneous flow of water in both the saturated and unsaturated flow regions is evaluated for various pumping rates and boundary conditions. The entire operation is programmed on an IBM 360 computer. Fulfillment of the project objectives will yield computer techniques for handling complicated water flow problems and additional information on inflow into wells.

(g) Drawdown in the near vicinity of wells has been evaluated for porous media which differ in permeability and specific yield. The feasibility of utilizing computer operation for rapid analysis of complex flow problems has been demonstrated.

(h) "Computer Methods for Transient Analysis of Water-Table Aquifers," George S. Taylor and James N. Luthin, Water Resources Res., Vol. 5, Feb. 1969.

UNIVERSITY OF OKLAHOMA, School of Aerospace and Mechanical Engineering, Norman, Oklahoma 73069. Dr. E. F. Blick, Professor.

(7554)

DRAG REDUCTION BY COMPLIANT COATING AND DUSTY AIR.

(b) U.S. Army Research Office -- Durham, N.C.

(d) Experimental and theoretical; applied research; M.S. and Ph.D. theses.

(e) To find the effect of compliant surfaces and dusty air on the turbulent skin friction drag. Low speed wind tunnels constitute the chief research tool.

(g) Turbulent skin friction drag reductions of up to 38% have been measured on flat plates using compliant coatings of polyurethane foam covered with polyvinyl chloride skin. The Reynolds number range was from 5×10^3 to 5×10^6 . Presently tests are being run on NACA 0009 airfoils to determine if compliant coatings will reduce their drag. Preliminary data have shown drag reductions of up to 25% with these airfoils. Drag reductions of up to 60% for flat plates and up to 32% for pipe flow were measured for "dusty air" (air with glass beads). The size of the glass beads was varied from 2 μ to 1680 μ . The smallest beads produced the largest drag reductions. Reynolds numbers ranged from about 1×10^4 to 7×10^4 for pipe flow and 6×10^3 to 1.5×10^6 for flat plate flow.

(h) "The Theory of Skin Friction Reduction by a Compliant Coating," E. F. Blick, pp. 409-426 of Viscous Drag Reduction, ed. C. S. Wells, Plenum Press, N.Y. 1969.

"Compliant Coating Skin Friction Experiments," E. F. Blick, R. R. Walters, H. Chu and R. Smith, AIAA Paper No. 69-165, AIAA 7th Aerospace Sciences Meeting, N.Y., Jan. 1969.

"Experimental Turbulent Skin Friction Coefficients of Compliant Coatings with a Foamy Substrate," R. Smith and E. F. Blick, J. Hydronautics, Vol. 3, No. 2, pp. 100-102, 1969.

"Compliant Surface Drag as a Function of Speed," H. Chu and E. F. Blick, J. Spacecraft and Rockets, Vol. 6, No. 6, pp. 763-764, 1969.

"Fluid Flow Phenomena in Dusty Air," M. Boyce and E. F. Blick, ASME Paper No. 69-WA/FE-24, Winter Annual Meeting, Los Angeles, Calif., Nov. 1969.

OREGON STATE UNIVERSITY, School of Engineering, Department of Civil Engineering, Corvallis, Oregon 97331. James G. Knudsen, Assistant Dean of Engineering.

(6778)

STRATIFIED RESERVOIR CURRENTS.

(b) Fed. Water Pollution Control Admin., U.S. Dept. of the Interior.

(c) Assoc. Prof. L. S. Slotta.

(d) Theoretical, experimental; basic, applied research; M.S. and Ph.D. theses.

(e) Means by which the quality of water withdrawn from a reservoir can be controlled and best quality maintained by selective withdrawal are to be determined. The investigation consists of a model study and a mathematical study via computer simulation to verify model behavior.

The computer simulation is an extension to the multifluid situation of the MAC method (Marker and Cell) developed by F. H. Harlow, et al., of

the Los Alamos Scientific Laboratory. The model study is directed to the influence of entering or initial water mass on current discharge patterns in the pool and final discharge from the reservoir.

(f) Completed.

(g) Part I. Entering stream flow effects on currents of a density stratified reservoir. Flow pattern parameters were found relating the existence, location, and magnitude of model internal density currents to entering streamflow characteristics. The extension of these model reservoir results to prototype conditions is developed.

Part II. The NUMAC Method for Non-homogeneous Unconfined Marker and Cell Calculations. A marker and cell method for computations involving non-homogeneous, incompressible, viscous fluid is developed. New boundary conditions which are useful in hydrodynamic and oceanographic simulation are presented. A wide range of applications are included featuring both graphic and numerical computer output. A flow chart and a program listing for implementing the method is available.

(h) "Stratified Reservoir Currents," Larry S. Slotta, E. Harvey Elwin, Howard T. Mercier and Michael D. Terry, Amer. Soc. Civil Engrs. Preprint No. 1097, Natl. Water Resources Engrg. Meeting, Memphis, Tenn., Jan. 1970.

"Streamflow Effects in a Stratified Model Reservoir," Larry S. Slotta and E. Harvey Elwin, Amer. Soc. Civil Engrs. Preprint No. 1098, Natl. Water Resources Engrg. Meeting, Memphis, Tenn., Jan. 1970.

(6780)

ROTATING CUTTERHEAD EFFICIENCY ON A HYDRAULIC SUCTION DREDGE.

(b) Electric Steel Company, Portland, Oregon.

(c) Assoc. Prof. L. S. Slotta.

(d) Experimental; applied research.

(e) Flow visualization studies used for evaluating rotating dredge cutterhead performance.

(f) Completed.

(h) "Flow Visualization Techniques Used in Dredge Cutterhead Evaluation," Larry S. Slotta, 1968 Proc. of WODCON, World Dredging Conf., Rotterdam, 1968, pages 56-77.

"Model Tests of Material Flow through Dredge Cutters and Suction Piping," Larry S. Slotta, ASME-IEEE Materials Handling Engrg. Conf., Portland, Ore., ASME Paper 69-MH-19, 7 p., Oct. 1969.

(7556)

TIDAL FLATS IN ESTUARINE WATER QUALITY ANALYSIS.

(b) Federal Water Pollution Control Admin.

(c) David A. Bella, Asst. Prof.

(d) Experimental and theoretical.

(e) The project involves the study of estuarine water quality with particular emphasis on the role of tidal flat areas. Computer simulation methods are employed along with experimental work.

(g) Developed finite-difference procedures and measured oxygen uptakes of tidal flat muds.

(7557)

AIRPHOTO ANALYSIS OF OCEAN OUTFALL DISPERSION.

(b) Federal Water Pollution Control Admin.

(c) Prof. Fred J. Burgess.

(d) Experimental; field investigation; Ph.D. thesis.

(e) To develop theory and technology for use of aerial photography and photogrammetric methods for determining dispersion rates, diffusion coefficients and other factors that are needed for the design or monitoring of waste discharge into the ocean through ocean outfall sewers.

- (g) Methodology for obtaining satisfactory airphoto imagery has been developed. Data processing methods, computer programs, and photodensitometer instruments have been completed and placed into use. Analysis of several sets of airphoto imagery has yielded results that agree with best techniques for in situ sampling from boats.

(7588)

COMPUTER SIMULATION OF EUTROPHICATION.

- (b) Office of Water Resources Research.
(c) David A. Bella, Asst. Prof.
(d) Theoretical.
(e) Computer methods are employed to mathematically model the aquatic environment including biological factors.
(g) The importance of algal sinking velocities and vertical mixing in a lake has been demonstrated. A lake dissolved oxygen model has been developed and studied.
(h) Two papers have been submitted for publication, one being accepted with other being reviewed.

(7559)

COMPUTER SIMULATION OF ESTUARINE DISPERSION.

- (b) National Science Foundation.
(c) David A. Bella, Asst. Prof.
(d) Theoretical.
(e) Computer methods are employed to study the nature of estuarine dispersion.
(g) The build up of pollutants in the vicinity of the outfalls during slack water periods has been studied.
(h) "Effect of Intra-Tidal Variations on Longitudinal Dispersion in Estuaries," M. D. Diska and D. A. Bella, 16th Ann. Spec. Conf., Hydraulics Div., ASCE, M.I.T., Aug. 1968, published by the Drexel Institute of Technology.
"A Note on Estuarine Water Quality Simulation Models," D. A. Bella, Proc. Natl. Symp. on Analysis of Water-Resources Systems, Amer. Water Resources Assoc., Univ. of Denver, Denver, Colo., July 1968.

(7560)

ADSORPTION OF VIRUS-SIZED PARTICLES IN POROUS MEDIA.

- (b) National Science Foundation.
(c) R. W. Filmer, Asst. Prof.
(d) Experimental and theoretical.
(e) A study of the variables affecting adsorption of ultra-small protein particles from suspension in ground water by the surrounding porous medium.

(7561)

APPLIED HYDRODYNAMICS - MOORING SYSTEM DYNAMICS.

- (b) National Science Foundation - Sea Grant.
(c) R. W. Filmer, Asst. Prof.
(d) Experimental and theoretical.
(e) Development of a computer model for two-point mooring systems subject to dynamic loading.

(7562)

APPLIED HYDRODYNAMICS - LOW VELOCITY OCEAN CURRENT MEASUREMENT.

- (b) National Science Foundation - Sea Grant.
(c) R. W. Filmer.
(d) Experimental.
(e) Development of electronic device for measurement of magnitude and direction of small ocean currents. Second phase of the project will be one of data collection for use in planning outfalls, etc.

OREGON STATE UNIVERSITY, School of Science, Department of Oceanography, Corvallis, Oregon 97331. John V. Byrne, Department Chairman.

(7563)

MODEL STUDY OF DOUBLE KELVIN WAVES.

- (c) D. Caldwell.
(g) Sequences of streak photographs of oscillatory modes trapped on the edge of a circular sill in a rotating basin have been obtained. The dispersion curve is now being constructed from measurements of wave-length and phase speed (derived from those photographs) as functions of the generator frequency. So far agreement with the Longuet-Higgins theory is quite good. The attenuation seems to be greater than would be expected from bottom friction.

(7564)

WIND WAVE PROPERTIES.

- (c) G. F. Beardsley.
(g) Surface wave height, two mutually perpendicular surface wave slopes, and subsurface wave pressure have been measured simultaneously for several hours in deep water. Similar measurements will later be made in conjunction with subsurface velocity measurements.
Two three-component spherical drag probes have been built and preliminary calibrations have been made. The associated electronics utilize simple variable inductance circuits and are entirely contained within the probe support. The spherical probe head is 5 cm. in diameter and is sensitive to both fluid drag forces and to fluid acceleration forces. The response time is less than 0.1 sec. and the dynamic range is 30 to 1. If the probes are used to measure wave orbital velocities near the surface, the acceleration term is less than 10% of the drag term for wave amplitudes greater than 45 cm.
A technique has been developed to remove from the probe outputs the effects of wave orbital velocities as predicted by linear wave theory from the surface height and slope records. From the residual output, velocities due to turbulence or second order wave effects may be determined.

(7565)

GENERATION OF LONGSHORE CURRENTS.

- (c) M. S. Longuet-Higgins.
(g) Expressions for lateral thrust, local and mean longshore stress in the surf zone are derived. After making an assumption for the variation of horizontal eddy viscosity, a family of longshore current profiles is obtained whose form depends only upon a single nondimensional parameter, P . This parameter is a function of bottom drag, beach slope and a constant characteristic of breaking waves. The current profiles are of simple analytic form, having a maximum in the surf zone and tending to zero at the swash line. Comparison with the laboratory experiments of Galvin and Eagleson (1965) shows remarkably good agreement if the drag coefficient C is taken as 0.010. The theoretical profiles are insensitive to the exact value of P , but the experimental results suggest that P never exceeds a critical value of $2/5$.

(7566)

LONG-PERIOD FLUCTUATIONS IN OCEAN CURRENTS.

- (c) M. S. Longuet-Higgins.
(g) Kelvin waves will follow a curved, vertical boundary, so long as the radius of curvature is not less than a certain critical limit. If

this condition is satisfied, then it is possible for an island to trap free energy with certain characteristic frequencies of oscillation, calculated in the paper. It is shown how periodic oscillations, such as tides or inertial oscillations, generate forced motions in the neighborhood of an island with vertical or sloping sides, and how these are associated with a steady rectified current circulating the island. The theoretical prediction that a steady current circulates the island is verified by a simple model experiment. The result may help to explain some earlier observations by Stommel (1954) on the drift velocities of free floats in the neighborhood of Bermuda.

A calculation of the free oscillations of fluid on a hemisphere bounded by meridians of longitude, undertaken in collaboration with Dr. S. Pond, has now been completed and accepted for publication in Phil. Trans. Roy. Soc. A. This calculation shows, by a particular example, some of the unexpected types of oscillation that can occur in a large ocean basin of dimensions comparable to the Pacific or Atlantic Oceans.

- (h) "On the Reflexion of Wave Characteristics from Rough Surfaces," J. Fluid Mech., 37, 231-250, (1969).
 "On the Trapping of Long-Period Waves Round Islands," J. Fluid Mech. 37, 773-784.
 "On the Transport of Mass by Time-Varying Ocean Currents," Deep-Sea Res., 16, 431-477 (1969).

PENNSYLVANIA STATE UNIVERSITY, College of Engineering, Department of Civil Engineering, Hydraulics Laboratory, University Park, Pennsylvania 16802. Dr. B. A. Whisler, Department Head.

(6207)

TRANSITIONS IN SUPERCRITICAL FLOW.

- (b) Pennsylvania Dept. of Forests and Waters.
 (c) Assoc. Prof. F. L. Blue, Jr.
 (d) Experimental; applied research; design; doctoral thesis.
 (e) Transitions of three different shapes were tested for Froude numbers varying from 1.2 to 3.2 representing test flows of 0.57 to 4.47 cfs. Each transition connected an upstream rectangular channel with a downstream trapezoidal channel, all three parts lying on one straight centerline. One transition shape had warped walls. The other two had plane walls: one with a vertical surface above a sloping surface, the other with a sloping surface above a vertical one. Each shape was tested for three approach-flow depths and for three transition lengths for each flow depth. Additional observations of the effects of increased invert slope in the transition, or in the transition and the trapezoidal channel, were included in the doctoral thesis.

- (f) Completed.
 (g) Graphs summarize the variation of the water surface along the channel walls and centerline, caused by the wave patterns of supercritical flow. These graphs are a basis for designing transitions of the three shapes tested. A guide is offered for application of the data to actual design.
 (h) "Open-Channel Transitions in Supercritical Flow," F. L. Blue, Jr. and H. Y. Rajagopal, Penn. State Univ. Engrg. Res. Bull. B-98, 85 pp., April 1969.
 "Transitions in Supercritical Flow: Expansions from Rectangular to Trapezoidal Sections," H. Y. Rajagopal, Doctoral thesis, Civil Engrg. Dept.,

Penn. State Univ., Sept. 1969. (Available from University Microfilms, Ann Arbor, Mich.)

(6208)

BEDLOAD FORMULAS.

- (b) Soil and Water Conservation Research Div., U.S. Dept. Agric., Agric. Research Service.
 (c) Prof. Sam Shulits, Civil Engrg. Dept., University of New Brunswick, Fredericton, N. B., Canada.
 (d) Analytical; applied research.
 (e) An attempt to resolve the dilemma of the many existing bedload formulas and an inquiry into their limitations and serviceability. Fourteen of the best known and most used formulas were programmed in Fortran IV for the IBM 360, Model 67, and were also plotted with a subroutine to facilitate comparison.
 (f) Completed.
 (g) Three of the programmed formulas were selected as representative of the main types of bedload formulas and as affording adequate agreement with the best known and most used formulas. Of the formulas in which bedload is a function of discharge, the Schoklitsch 1934 formula was selected. For those in which the bedload is a function of the tractive force, two formulas emerged as representative, the Straub-DuBoys and the Meyer-Peter and Müller formulas. These three formulas may be considered valid for effective diameters from 0.3 to 7 mm. The Meyer-Peter and Müller formula could be employed with caution up to 30 mm on the basis of a single series of uniform-grain tests for the larger diameters. The Schoklitsch formula has the advantages of a simple form and the direct production of a rating curve of bedload versus discharge.
 (h) "Bedload Formulas," Sam Shulits and Ralph D. Hill, Jr., Penn. State Univ., Dept. of Civil Engrg. Hydraulics Lab. Bull., 192 pp., Dec. 1968 (out of print; for information on future republication write E. T. Engman, N. E. Watershed Research Center, 111 Research Building A, University Park, Pa. 16802).

(7567)

VERTICAL TRANSPORT OF COAL BY PIPELINE.

- (b) Pennsylvania Dept. of Mines and Mineral Industries.
 (c) Asst. Prof. J. R. Reed.
 (d) Analytical; developmental; Master's thesis.
 (e) Two-phase upward transport is being studied in order to determine its economic advisability for deep mines. Experimental research may follow.

PENNSYLVANIA STATE UNIVERSITY, Institute for Science Engineering, Ordnance Research Laboratory, P. O. Box 30, University Park, Pennsylvania 16801. J. C. Johnson, Laboratory Director.

(2832)

MEASUREMENT OF FORCES AND PRESSURES ON A MODEL IN A WATER TUNNEL.

- (b) Naval Ordnance Systems Command.
 (c) Mr. George B. Gurney.
 (d) Experimental and developmental.
 (e) The problem concerns the measurement of thrust, torque body forces, and pressures on various hydrodynamic bodies. Measurements are made on bodies over a range of velocities up to 60 ft/sec and under pressure simulating fully developed cavitating flows.
 (g) Strain gaged force balances are used to sense body forces. These balances are capable of completely submerged operation. A Planar Motion

- Mechanism is available for determining dynamic stability derivatives required in the equation of motion of submerged bodies. The capability of measuring unsteady thrust is also available.
- (h) "The Garfield Thomas Water Tunnel," A. F. Lehman, ORL Unclassified External Rept. NORD 16597-56, Sept. 30, 1959.
- (3807)
THERMODYNAMIC EFFECTS ON CAVITATION.
(b) National Aeronautics and Space Admin.
(c) J. William Holl.
(d) These investigations are both experimental and theoretical.
(e) These investigations are carried out in the high speed cavitation tunnel employing various working fluids. At the present time, the primary fluid is Freon 113. Thermodynamic effects are investigated for both developed and limited cavitation over a range of temperatures and velocities. Analytical investigations are also being conducted.
- (h) "Thermodynamic Effects on Desinent Cavitation on Hemispherical Nosed Bodies in Water at Temperatures from 80 Deg. F. to 260 Deg. F.," J. W. Holl and A. L. Kornhauser, Trans. A.S.M.E., J. Basic Engrg., March 1970.
"Thermodynamic Effects on Developed Cavitation in Water and Freon 113," Michael L. Billet, Master's thesis, Dept. of Aerospace Engrg., Penna. State Univ., March 1970.
- (6557)
CHARACTERISTIC VIBRATIONS AND ACOUSTIC RADIATION FROM SHELLS OF ARBITRARY SHAPE.
(b) Naval Ordnance Systems Command.
(c) Dr. Maurice Sevik.
(d) Experimental and theoretical.
(e) A study of propulsor blade vibrations.
(g) Propulsor blades have complicated geometries and hence vibrate in modes which are difficult to predict. The characteristic vibrations of such blades, idealized as thin shells, are being investigated by means of numerical methods. The effects of the liquid surrounding the blades are also included. The computer results will be verified experimentally.
- (h) "Vibration Analysis of a Shell by Finite Element Methods," H. Tsushima, Master's thesis, Dept. of Aerospace Engrg., The Penn. State Univ., Sept. 1969.
- (6558)
MIXING OF GASES IN LIQUID JETS.
(b) Naval Ordnance Systems Command.
(c) Dr. Maurice Sevik.
(d) Experimental, theoretical; basic research.
(e) A study of the bubble formation process in a turbulent jet and the resulting acoustic radiation.
(g) When a gaseous jet mixes with a turbulent liquid jet, acoustic radiation is observed. In this study, the characteristic bubble size and distribution has been determined in terms of the characteristics of the liquid and the gas. The results of this investigation will be available within six months.
- (7568)
THE EFFECT OF SURFACE CHARACTERISTICS ON LIMITED CAVITATION.
(b) Naval Ordnance Systems Command.
(c) J. William Holl.
(d) The investigations are both experimental and theoretical.
(e) The effect of various surface characteristics
- such as porosity and contact angle on incipient and desinent cavitation is being studied in a water tunnel.
- (f) Inactive.
(h) "The Influence of Porosity and Contact Angle on Incipient and Desinent Cavitation," Surender Kumar Gupta, Master's thesis, Dept. of Aerospace Engrg., Penna. State Univ., Dec. 1969.
- (7569)
CAVITATION INCEPTION CHARACTERISTICS OF REAL SURFACE ROUGHNESSES.
(b) Naval Ship Research and Development Center.
(c) J. William Holl; R. E. Arndt, 233-C Hammond Building.
(d) Both experimental and theoretical.
(e) Problem concerns the cavitation characteristics of real surface roughness such as barnacles. Cavitation tests are to be conducted in a water tunnel and roughnesses are researched in the field.
- (7570)
INVESTIGATION OF FLUCTUATING BLADE SURFACE PRESSURES.
(b) Naval Ordnance Systems Command.
(c) Mr. E. P. Bruce.
(d) Experimental and theoretical.
(e) The objective of this program is the measurement of unsteady blade surface pressures on both rotating and stationary blade surfaces. A rotating cascade is being designed whose blade dimensions are of sufficient size to permit installing sensitive high response pressure transducers along the blade chord. With prescribed inflow distortions or turbulence levels, the experimental time varying blade surface pressures shall be obtained. A correlation between the experimental results and a number of existing theoretical solutions shall be performed. In addition, efforts to develop an analytical solution to the unsteady flow through a cascade of blades are in progress.
- (7571)
EXPERIMENTAL INVESTIGATION OF CASCADE GEOMETRIES.
(b) Naval Ordnance Systems Command.
(c) Messrs. J. R. Ross and W. S. Gearhart.
(d) Experimental and applied research.
(e) The development of blading having superior hydrodynamic performance has required the use of cascade geometries for which no experimental data exists. On this basis, a subsonic porous wall cascade tunnel with an aspect ratio of two was designed and made operational. Trailing edge loaded profiles of high chord to spacing ratios are being tested. In addition, efforts are in progress to modify existing cascade potential solutions to reflect the displacement thickness of the blade boundary layer. Predictions based on analytical solutions corrected for boundary layer effects shall be correlated with experimental results.
- (7572)
CORRELATION BETWEEN FLUCTUATING BLADE PRESSURES AND RADIATED NOISE IN AXIAL FLOW COMPRESSORS.
(b) Naval Ordnance Systems Command.
(c) Mr. D. E. Thompson.
(d) Experimental and theoretical.
(e) Due to the operation of the blading of axial flow turbomachines in distorted and turbulent inflows, unsteady blade pressures exist. These fluctuating blade pressures generate sound which is ultimately radiated to the far field. For various inflow conditions, i.e., distorted circumferential veloc-

ity distributions, and turbulence of different intensities and eddy sizes, the fluctuating blade pressures will be measured and correlated with simultaneous measurements of the radiated sound. The axial flow compressor is designed to permit tests at various operating conditions, i.e., rotor-stator spacing, rotor rpm, etc. Where the inflow and compressor characteristics match the assumptions used in a particular theory designed to predict the acoustic radiation from such a turbomachine, an attempt will be made to correlate the experimental and theoretical results.

(7573)

AN INVESTIGATION INTO UNSTEADY PROPULSOR FORCES.

- (b) Naval Ordnance Systems Command and Naval Ships Systems Command.
- (c) Messrs F. E. Smith and D. E. Thompson.
- (d) Experimental and theoretical.
- (e) Propulsors experience unsteady forces due to operation in the wakes shed from control surfaces and due to operation in a turbulent inflow. An investigation is in progress whose purpose is to measure the unsteady propulsor forces accurately and correlate these measurements with theoretically determined values. An investigation will then be made into the effects of various propulsor configurations, i.e., number of blades, advance ratio, etc., and the effects of varying the inflow characteristics. Two types of propulsors, a propeller and a pumpjet, are being studied. Both are operated in the free stream in order that the complex inflow, that would be present when an upstream body exists, is eliminated. An attempt will be made to correlate the experimental and theoretical results. A later phase of this investigation will involve measurement of unsteady propulsor forces in the complex wake behind an underwater vehicle.
- (g) "Unsteady Propeller Forces," L. M. Casellini, Master's thesis, Dept. of Aerospace Engrg., Penna. State Univ., 1965.
- "Measurement, Correlation with Theory, and Parametric Investigation of Unsteady Propeller Forces and Moments," R. J. Boswell, Master's thesis, Dept. of Aerospace Engrg., Penna. State Univ., Dec. 1967.

PENNSYLVANIA STATE UNIVERSITY, Systems and Controls Laboratory, University Park, Pennsylvania 16802.
Professor J. L. Shearer, Laboratory Director.

(7807)

FLUIDIC OPTIMIZER.

- (b) Natl. Defense Education Act Fellowship.
- (d) Analytical and experimental; applied research, Ph.D. investigation.
- (e) The purpose of this research is to study the performance of relatively simple extremum control systems which may be realized using fluidic components and to construct a fluidic extremum controller suitable for maximizing prime mover performance. One version employs acceleration measurement using a seismic sensor called a celsig. The other version employs a pulse rate generator to sense the output shaft speed. Initial analog computer studies are being verified by experiments with actual system hardware.
- (h) Ph.D. thesis due in Fall 1970; See SCL Reports Nos. 8, 9, 10.

(7808)

FLUID LINE DYNAMICS.

- (b) Bell Telephone Labs., NASA Grant, Rockwell Mfg.

Co. Grant.

- (c) A. J. Healey, J. L. Shearer.
- (d) Analytical and experimental; applied research, M.S. and Ph.D. thesis investigation.
- (e) Various simplified models of hydraulic and pneumatic lines have been studied for cases of interest to designers of hydraulic and pneumatic control systems, including fluidic systems. Both transient response and frequency response characteristics have been considered with emphasis on finding the simplest possible, useful models for:
 - (a) hydraulic lines with small flow resistance;
 - (b) water hammer in liquid-filled lines;
 - (c) frequency response and transient response of small-bore pneumatic lines (with some work including effects of junctions); and, (d) applications of the hydraulic mean diameter concept to unsteady flow.
- (h) "Frequency Response of Round and Rectangular-Sectioned Pneumatic Transmission Lines," R. J. Carlson, M.S. thesis, Dec. 1969, The Penna. State Univ., Dept. of Mech. Engineering.
- "Frequency Response of Rectangular Pneumatic Transmission Lines," A. J. Healey and R. J. Carlson, Paper No. 69-WA/FLCS-5, ASME, 1969 Winter Annual Meeting, Los Angeles, Calif.
- "A Simplified Model for a Fluid Transmission Line," R. G. Leonard, Ph.D. thesis, June 1970, The Penna. State Univ., Dept. of Mech. Eng., (ASME paper in preparation). Further details in SCL Reports Nos. 8, 9, 10.

(7809)

FLUID JET AMPLIFIER DYNAMICS.

- (b) NASA Grant, Bell Telephone Labs. Research Contract.
- (c) J. L. Shearer, A. J. Healey.
- (d) Analytical and experimental; applied research, Ph.D. thesis investigation.
- (e) This work involves some basic studies of the dynamic response of free jets to perturbations near the nozzle which tend to cause the jet to be deflected as it moves downstream. This work was initiated because there is a need to understand the dynamic behavior of jets in fluid amplifiers and fluidic devices. Most of this work concerns the jets subjected to sinusoidal input pressure disturbances applied normal to the jet as it leaves the nozzle. Simplified mathematical models are being developed to describe some of the complex dynamic behavior which has been observed so far.
- (h) See SCL Reports Nos. 8, 9, 10.

(7810)

MODULATION OF JET THRUST BY INDUCED SWIRL (VORTEX FLOW).

- (b) NASA Grant.
- (d) Analytical and experimental; applied research, Ph.D. thesis investigation.
- (e) Vortex generation in the exhaust nozzle of a jet engine is being investigated as a possible means for modulating the thrust of an engine rapidly without using heavy and expensive mechanical spoilers (a considerable time delay is involved in waiting for change of thrust after changing jet engine power setting). This work has involved analytical studies of flow through thrust producing nozzles with swirl induced in the inlet flow, and small scale experiments as well as larger scale experiments in which swirl was induced with upstream guide vanes have been carried out. Large scale work was carried out in the 40' x 80' wind tunnel at NASA-Ames Research Center, Moffett Field, California. Simplified mathematical models to describe and predict the thrust and

mass flow rate modulation are being developed.
(h) See SCL Reports Nos. 8, 9, 10.

- (7811)
OSCILLATORY VANE DIGITAL FLOW RATE SENSOR.
(b) USAF Fellowship, NASA Grant.
(d) Experimental investigation; applied research, M.S. thesis investigation.
(e) This project involved an experimental study of an oscillating vane digital flow rate sensing scheme to determine the graphical relationship between the passing air flow rate and the vibration frequency of an oscillating vane in a two-dimensional, converging-diverging passage. Theories studied include the effects of varying the diffuser angle from 20° to 50° (total included angles) and many different combinations of vane height and vane width. Whereas most of the experiments were carried out with air at low pressure, a limited number of experiments were carried out with helium to explore the effects of varying gas density.
(f) Completed for time being.
(h) "Experimental Study of an Oscillating Vane Digital Flow Rate Sensor," M.S. thesis, M. B. Song, June 1969, The Penna. State Univ., Dept. of Mech. Eng.

- (7812)
HELMHOLTZ RESONATOR RESPONSE WITH F. M. PRESSURE SIGNALS.
(b) Ford Foundation Fellowship.
(c) A. J. Healey.
(d) Analytical and experimental; applied research, M.S. thesis investigation.
(e) Because a Helmholtz resonator is one important type of fluid network which can be used to demodulate F. M. signals generated by fluidic sensors, a basic investigation was initiated to determine the dynamic response characteristics of a Helmholtz resonator to frequency modulated input pressure signals. In this work the resonator is modelled mathematically and a numerical technique for F. M. signal analysis is employed to show the basic difference between input-to-output phase shift detection and input-to-output frequency detection. The use of a low modulation index transfer function is discussed with experimental results which reveal its limitations. A numerical procedure is recommended for designing demodulation circuits over a range of modulation frequencies.
(f) Completed.
(g) M.S. thesis in preparation. "Helmholtz Resonator Response with F. M. Pressure Signals," by A. J. Healey and D. W. Fowler, Proc. Fourth Fluidics Conf., pp. F1-1 to F1-16, March 1970, British Hydromechanics Res. Assoc., Cranfield, Bedford, England.

- (7813)
EFFECTS OF VENTS AND LOADS ON DYNAMIC RESPONSE OF FLUID AMPLIFIERS.
(b) NASA Grant, Army Research Office Contract.
(c) A. J. Healey.
(d) Analytical and experimental; applied research, M.S. thesis investigation.
(e) In the design of proportional or analog fluidic systems, extra care must be taken because of the problems of signal noise and the dynamic response limitations of amplifiers, and other active components. This work has concentrated on modeling the internal flow within amplifiers and improving the understanding of geometry effects and loading effects on amplifier response. Both real size and large scale model amplifiers have been employed for experiments and some insight has been gained into the causes of resonance and instability,

particularly with "blocked receiver" loads. The long term goal of this work is to establish techniques for the design of amplifiers having specially desired response characteristics.
(g) M.S. thesis in preparation. "Vent Effects on the Response of a Proportional Fluid Amplifier," A. J. Healey, Trans. ASME, Series D, Vol. 90, No. 1, March 1968, pp. 90-96.
"Dynamic Response of Analog Fluid Amplifiers," A. J. Healey, Proc. Symp. on Fluidics and Internal Flows, Part I - Fluidics, Oct. 1968, The Penna. State Univ., Dept. of Mech. Eng., pp. 1-87 to 1-114.

- (7814)
A FLUIDICS REFERENCE CENTER.
(b) College of Engineering, and the Conference Center.
(d) Information retrieval.
(e) References on fluidics are permanently entered into an information bank which is accessible through both computerized and manual retrieval procedures. The various aspects of fluidics and related subjects are coded into main areas (up to 26) and each main area is divided into appropriate subareas (up to 36 for each). The extra effort and talent required for this form of indexing is justified by the additional flexibility afforded to the user in selecting references in a specific area of fluidics.
(h) "Research Report No. 9," Systems and Controls Lab., Penna. State Univ., Apr. 1969, pp. 4-5.
"Research Report No. 10," Systems and Controls Lab., Penna. State Univ., Oct. 1969, pp. 4-6.

UNIVERSITY OF PITTSBURGH, School of Engineering,
Chemical and Petroleum Engineering Department, Pitts-
burgh, Pennsylvania 15213. Dr. George E. Klinzing,
Associate Professor.

- (7574)
TURBULENCE WALL FLUCTUATIONS OF FLEXIBLE BOUNDARIES IN ENTRANCE SECTIONS OF FLEXIBLE SLASTIC TUBES.
(d) Experimental and theoretical; basic and applied research; master and doctoral theses.
(e) Measurement of flexible wall fluctuations by transducers in the entrance section of tubes to ascertain interaction relations between turbulent fluid flow and flexible boundaries.
(g) For large pressures steady wave wall deformation found along with development lengths for steady state flow profiles in the turbulent regime. Wall oscillations in vibration free system indicate Tollmien-Schlichting wave production and damping by flexible tube.
(h) M.S. thesis, P. H. Phillips, Univ. of Pittsburgh;
M.S. thesis, W. Yu, Univ. of Pittsburgh.

- (7575)
EFFECT OF FLEXIBLE BOUNDARIES ON AEROSOL FLOW IN THE TURBULENCE REGIME.
(d) Experimental and theoretical; basic and applied research; doctoral thesis.
(e) Measurement of overall reduced pressure drop in system in effort to combine effect of flexible boundary - particle concentration to doubly effect a reduction in turbulent eddy viscosity. Deposition of aerosol concentration and concentration profile effects studied.
(h) Anticipated Ph.D. thesis, L. Peters, Univ. of Pittsburgh.

UNIVERSITY OF PITTSBURGH, School of Engineering, Department of Civil Engineering, Pittsburgh, Pennsylvania 15213. Dr. Joel I. Abrams, Department Chairman.

(7577)

STOCHASTIC OPEN CHANNEL FLOW.

- (b) Office of Water Resources Research.
- (c) Prof. Chao-Lin Chiu.
- (d) Analytical, experimental.
- (e) Stochastic approach is used to study effect of irregular channel shape and slope on the water surface profile and flow velocity.
- (g) The diffusion coefficient of particles undergoing "random walk" along the periphery of channels is found to be an adequate statistical geometrical measure of the channel roughness. The irregular shape and slope of an open channel are simulated by a Brownian motion model.
- (h) "Stochastic Open Channel Flow," Chao-Lin Chiu, Proc. ASCE, J. Engrg. Mech. Div., Vol. 94, No. EM3, June 1968.
- "Statistical Roughness Parameter as Indicator of Channel Flow Resistance," Chao-Lin Chiu and G. Almanzar, J. Water Resources Res., Vol. 6, No. 2, April 1970.

(7578)

TIME-VARYING LINEAR AND NONLINEAR MODELS OF RAINFALL-RUNOFF RELATION.

- (b) Office of Water Resources Research, U.S. Dept. of the Interior.
- (c) Professor Chao-Lin Chiu.
- (d) Analytical, experimental.
- (e) Development of time-varying linear and nonlinear system models of rainfall-runoff relation.
- (g) Linear time-varying and nonlinear time-varying models of rainfall-runoff relation have been developed.
- (h) "Linear Time-Varying Model of Rainfall-Runoff Relation," Chao-Lin Chiu and Ronald P. Bittler, J. Water Resources Res., Vol. 5, No. 2, April 1969.
- "Nonlinear Time-Varying Model of Rainfall-Runoff Relations," Chao-Lin Chiu and J. T. Huang, presented at 50th Meeting, Amer. Geophys. Union, Washington, D.C., April 1969. Undergoing review for journal publication.

(7579)

SECONDARY FLOW IN STRAIGHT CHANNELS.

- (b) NSF.
- (c) Professor Chao-Lin Chiu.
- (d) Analytical, semi-empirical, applied research.
- (e) Development of method of calculating secondary currents in an entire transverse cross-section of straight channels. Study of the role of secondary flow in hydraulics.
- (g) The method developed involves the use of different sets of curvilinear coordinate systems, in different regions of a cross-section, that consist of isovels of primary flow and their orthogonal trajectories.
- (h) "Calculation of Secondary Flow in Straight Channels," Chao-Lin Chiu and Teh-Shee Lee, presented at ASCE Hydraulics Div. Spec. Conf., Minneapolis, Aug. 1970.
- "Factors Determining the Strength of Secondary Flow," Chao-Lin Chiu, J. Engrg. Mech. Div., ASCE, Vol. 93, No. EM4, August 1967.
- "Effect of Secondary Flow on Sediment Transport," Chao-Lin Chiu and John E. McSparran, J. Hyd. Div., ASCE, Vol. 92, No. HY5, Sept. 1966.
- "The Role of Secondary Currents in Hydraulics," Chao-Lin Chiu, Proc. XIIth Congr. IAHR, Paper No. Vol. 1, Fort Collins, Sept. 1967.

(7580)

STOCHASTIC HYDRODYNAMICS OF SEDIMENT TRANSPORT.

- (b) Natl. Aeronautics and Space Admin.
- (c) Professor Chao-Lin Chiu.
- (d) Experimental, analytical; M.S., Ph.D. thesis.
- (e) A stochastic model is used in a study of sediment transport by the Monte Carlo Simulation Method.
- (g) Results include the three-dimensional unsteady sediment distribution that cannot be obtained by conventional techniques, as well as the steady uniform sediment distribution. The diffusion coefficient of sediment is also studied by the Monte Carlo Simulation Method used.
- (h) "Stochastic Hydrodynamics of Sediment Transport," Chao-Lin Chiu and K. C. Chen, J. Engrg. Mech. Div., ASCE, Vol. 95, No. EM5, October 1969.
- "Stochastic Model of Motion of Solid Particles," Chao-Lin Chiu, J. Hyd. Div., ASCE, Vol. 93, No. HY5, Proc. Paper 5445, Sept. 1967.

(7581)

HYDROLOGIC SYSTEMS MODELING.

- (b) Office of Water Resources Research.
- (c) Dr. Rafael G. Quimpo.
- (d) Theoretical and experimental; applied and basic.
- (e) The purpose of the study is to determine the intrinsic differences among time series models of hydrologic processes and determine their suitability in water resources design applications.
- (g) Kernels of linear stochastic models (Markov, autoregressive and self-similar) have been developed. These kernel functions, as in deterministic models, may be related to the storage characteristics of the physical systems.
- (h) "Simulation of Oxygen Utilization in a Storage-Treatment Plant System," J. C. Phillips, R. G. Quimpo and J. P. Miller, Proc. IASH-UNESCO Symp. on Analog and Digital Computers in Hydrology, Tucson, Ariz., Dec. 1968.
- "Use of Continuous Streamflow Simulator in Water Resources Design," Rafael G. Quimpo, Proc., 13th Congr. Intl. Assoc. Hyd. Res., Kyoto, Japan, Vol. 1, Sept. 1969.
- "Reduction of Serially Correlated Hydrologic Data," R. G. Quimpo, Bull. Intl. Assoc. Scientific Hydrology, Vol. 14, No. 4, Dec. 1969.

PURDUE UNIVERSITY, Department of Agricultural Engineering, Lafayette, Indiana 47907. Dr. G. W. Isaacs, Department Head.

(040W)

EFFECT OF PESTICIDE RESIDUES AND OTHER ORGANO-TOXICANTS ON THE QUALITY OF SURFACE AND GROUND WATER RESOURCES.

For summary, see Water Resources Catalog, Vol. 4, No. 5, 0396.

(3808)

PREDICTING RUNOFF AND GROSS EROSION FROM FARMLAND AND DISTURBED AREAS.

(Also see Agric. Research Serv., Corn Belt Branch, Project No. 4275).

- (b) Soil and Water Conservation Div., U.S. Dept. of Agric. and Agric. Experiment Sta., Purdue Univ.
- (c) Mr. Walter H. Wischmeier, ARS-SWC.
- (d) Experimental; development.
- (e) The relationship of numerous rainstorm characteristics, topographic features, soil characteristics and surface conditions to surface runoff and soil erosion are being evaluated from plot data obtained under natural and/or simulated rainfall.

- (g) The soil-erodibility equation developed in 1967 from field-plot data was found valid and useful also for predicting sediment yields from disturbed areas such as commercial construction sites. Management effect on disturbed areas was studied by determining under simulated rainfall relative sediment yields from six construction-sites surface conditions. The relative water-retention and erosion-control merits of various approaches to minimum tillage for corn were investigated in detail under simulated rainstorms in relation to their effects on infiltration, runoff velocity, and susceptibility of the surface to particle-detachment by rainfall or runoff. As the treatment approached zero tillage, with adequate crop residues on the surface, soil-loss rates approached negligible magnitudes but runoff increased appreciably. The relation of quantity of surface residue to runoff and soil loss was studied both on tilled and untilled soil surfaces and with several degrees of slope.
- (h) "Effect of Cropping Intensity on Erosion and Infiltration," J. V. Mantering, L. D. Meyer, and C. B. Johnson, *Agron. Jour.* 60: 206-209, 1968. "Tillage and Land Modification for Water Erosion Control," L. D. Meyer and J. V. Mantering, *Proc. ASAE Tillage Conf.*, pp. 58-62, 1968. "Relation of Soil Properties to its Erodibility," W. H. Wischmeier and J. V. Mantering, *Soil Sci. Soc. Amer. Proc.* 33: 131-137, 1969. "Effect of Crop Row Spacing on Erosion and Infiltration," J. V. Mantering, and C. B. Johnson, *Agron. Jour.* 61: 902-905, 1969.

(4182)

MECHANICS OF SOIL EROSION BY WATER.

- (Also see Agric. Research Serv., Corn Belt Branch, Project No. 4275.)
- (b) Soil and Water Conservation Research Div., Agricultural Research Service, U.S. Dept. of Agric., and Agric. Experiment Sta., Purdue Univ.
- (c) Dr. L. D. Meyer, ARS-SWC.
- (d) Experimental, analytical, basic research.
- (e) The mechanics of soil erosion by water are being studied as a basis for an improved mathematical model for describing the erosion process.
- (g) The soil erosion process was mathematically simulated by considering soil detachment and transport by rainfall and runoff as separate but interrelated subprocesses. The influence of each was studied and the total approach field tested.
- (h) "Mathematical Simulation of the Process of Soil Erosion by Water," L. D. Meyer and W. H. Wischmeier, *Trans. Am. Soc. Agric. Engr.* 12(6): 754-758, 1969. "Small Amounts of Surface Mulch Reduce Soil Erosion and Runoff Velocity," L. A. Kramer and L. D. Meyer, *Trans. Am. Soc. Agric. Engr.* 12(5): 639-641, 1969. "Erosion Equations Predict Land Slope Development," L. D. Meyer and L. A. Kramer, *Agric. Engrg.* 50(9): 522-523, 1969.

(5810)

TREATMENT OF WATER FROM SMALL RESERVOIRS FOR DOMESTIC CONSUMPTION.

- (b) Agricultural Expmt. Sta., Purdue Univ.
- (c) Dr. E. J. Monke.
- (d) Experimental; applied and basic research.
- (e) To study various control measures as an aid for filtration of raw water supplies.
- (f) Completed.
- (g) With studies on electrophoretic control, the filter zeta-potential quickly approached an iso-electric condition when the pH level of colloidal-

laden inflow was around neutral. The filter efficiency was also greatest at this level. Evidence was presented that bacteria at the filter surface were positively charged. With pesticide residue control, the most efficient granular activated carbon filter was able to remove 99 percent of a chlorinated hydrocarbon, Dieldrin. Since the residue was in small amounts likely to be encountered under natural circumstances, the greatest length of filter was most effective for removal while granular size in the somewhat narrow range used was insignificant.

(6093)

MATHEMATICAL SIMULATION OF HYDROLOGIC EVENTS ON UNGAGED WATERSHEDS.

- (b) Office of Water Resources Research; and Agricultural Expmt. Sta., Purdue Univ.
- (c) Dr. L. F. Huggins.
- (d) Experimental and theoretical; basic and applied research.
- (e) Relationships describing the dynamics of the various components of the runoff process for small elemental areas within a watershed will be developed after which fundamental hydrodynamic equations will be utilized to integrate the spatially varied, time dependent outputs from all of the many elements within the watershed to obtain a composite runoff hydrograph.
- (f) Completed.
- (g) A comprehensive mathematical watershed model was developed. The model was based upon the concept of subdividing the watershed into a grid of small, uniform elemental areas and integrating the individual elemental responses into a composite runoff hydrograph.
- (h) "A Mathematical Model for Simulating the Hydrologic Response of a Watershed," L. F. Huggins and E. J. Monke, *Water Resources Res.* 4(3): 529-539, 1968. "Simulation of Overland Flow on Short Field Plots," G. R. Foster, L. F. Huggins, and L. D. Meyer, *Water Resources Res.* 4(6): 1179-1187, 1968.

(6771)

ANALYSIS OF SMALL PLOT INFILTRATION DATA.

- (b) Soil and Water Conservation Research Div., Agric. Research Service, U.S. Dept. Agric.; and Agricultural Expmt. Sta., Purdue Univ.
- (c) Dr. E. J. Monke.
- (d) Experimental and field investigation; applied research.
- (e) Overland flow field data from short erosion plots under simulated rainfall are being used to determine a relationship between the rate of surface runoff and depth and to correlate this relationship as well as depressional storage to surface roughness. Infiltration data will be separated from the runoff hydrographs and used to obtain parameters for infiltration equations.
- (f) Completed.
- (g) A kinematic overland flow model with a constant Darcy-Weisbach coefficient of friction adequately described overland flow on short, rough slopes. Regression fits of infiltration equations proposed by Green and Ampt, Horton, Philip, and Holton to experimental data for 52 tests on 13 different soils showed that all of the equations could be used to define the infiltration process. The difficulty of applying any of these equations would be in evaluating the equation parameters which were shown to vary widely in the completed study.
- (h) "Simulation of Overland Flow on Short Field Plots," G. R. Foster, L. F. Huggins, and L. D.

- Meyer, Water Resources Res. 4(6): 1179-1187, 1968.
- "Experimental Evaluation of Infiltration Equations," R. W. Skaggs, L. F. Huggins, E. J. Monke, and G. R. Foster, Trans. Amer. Soc. Agric. Engr. 12(6): 822-828, 1969.
- (7584)
WATER QUALITY CONTROL IN THE SOIL ECOSYSTEM.
(a) Agricultural Expt. Sta., Purdue Univ.
(b) Dr. E. J. Monke.
(c) Experimental, theoretical, field investigation, applied research.
(d) To study the dynamics of water and pollutant movement in unsaturated soil, to study the role of plant life in water quality management, and to evaluate treatment of polluted water by filtration through the soil mantle.
(e) Numerical techniques including the Peaceman-Rachford alternating direction implicit (ADI) method were used to analyze unsteady, two-dimensional, porous media flow systems which were only partially saturated. An approximate method for defining the conductivity function of unsaturated soils was proposed and verified. Also the movement of phosphorus in saturated soils was analyzed experimentally using radiological techniques. In a concurrent study, some effects of root-leaf temperature differences on plant growth response were determined using tomato plants with their roots systems exposed to a nutrient-solution mist culture.
(f) "An Approximate Method for Defining the Hydraulic Conductivity-Pressure Relationship for Soils," R. W. Skaggs, E. J. Monke, and L. F. Huggins, Am. Soc. Agric. Engr. Paper No. 69-742, 1969.
"Finite Difference Solutions of Unsteady, Two-Dimensional, Partially Saturated Porous Media Flow," C. R. Amerman, Ph.D. thesis, Purdue Univ., 1969.
"Some Effects of Root-Leaf Temperature Differences on Plant Growth Response," R. M. Alverson, M.S. thesis, Purdue Univ., 1970.
"An Approximate Method for Determining the Hydraulic Conductivity Function of Unsaturated Soil," R. W. Skaggs, Ph.D. thesis, Purdue Univ., 1970.
"Movement of Pollutant Phosphorus in Saturated Soils," P. R. Goodrich, Ph.D. thesis, Purdue Univ., 1970.
- (7585)
CHARACTERIZATION OF THE HYDROLOGY OF SMALL WATERSHEDS.
(a) Office of Water Resources Research, and Agricultural Expt. Sta., Purdue Univ.
(b) Dr. L. F. Huggins.
(c) Experimental, basic, applied, design.
(d) The project objective is to develop an analytical method to accurately describe the hydrologic response of natural watersheds to real or hypothetical storms independent of gaged records for a watershed.
(e) Present efforts are being directed toward improving the description of the infiltration and overland flow components of the hydrologic processes occurring during a storm event.
(f) "Laboratory Modeling and Overland Flow Analysis," K. C. Das, Ph.D. thesis, Purdue Univ., 1970.
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- (039W)
CHARACTERIZATION OF THE RATE OF WATER INFILTRATION INTO SOIL.
For summary, see Water Resources Research Catalog, Vol. 4, No. 2.0471.
(f) Completed.
(g) Rate of water infiltration was measured for surface-ponded sand-silt columns and field cores in the laboratory, for small field plots (1.16 by 1.16 m) by a sprinkler infiltrometer, and for larger field plots (12 by 35 ft) by a rainfall simulator. Results were assessed by the theoretically based Green-Ampt and Philip equations, and the empirical Horton and Holtan equations. For the sand-silt columns, the approximate theory of the Green-Ampt equation worked well for uniform conditions at different initial water contents, and for initially air-dry coarse-overfine stratifications, but not as well for fine-over-coarse stratifications. Some difficulty also was encountered in describing field-core rates, which generally compared more closely with small-plot sprinkler-determined rates when the soil surface was unprotected from sprinkler-drop impact. This suggests the possibility of a partial core-surface seal, perhaps somehow caused by the core-sampling process. Large-plot rainfall-simulator infiltration rates for 13 soils, determined by correcting for surface storage rates with an overland flow analysis, could be reasonably well described by any of the four equations, but the two empirical ones were somewhat better than the two theoretically based ones.
(h) "The Applicability of Darcy's Law," D. Swartzendruber, Soil Sci. Soc. Amer. Proc., Vol. 32, No. 1, pp. 11-18, 1968.
"Experimental Evaluation of Infiltration Equations," R. W. Skaggs, L. F. Huggins, E. J. Monke, and G. R. Foster, Trans. Amer. Soc. Agr. Engrs., Vol. 12, No. 6, pp. 822-828, 1969.
"Characterization of the Rate of Water Infiltration into Soil," D. Swartzendruber, R. W. Skaggs, and D. Wiersma, Tech. Rept. 5, Purdue Univ. Water Resources Research Center, Lafayette, Ind., 120 pp., Dec. 1968.
- (122W)
ELECTRICAL EFFECTS ON WATER INFILTRATION INTO SOILS.
For summary, see Water Resources Research Catalog, Vol. 4, No. 2.0467. See also (6166), 1968 issue.
(f) Experimental work completed, final report in preparation.
- (123W)
QUANTIFICATION AND PREDICTION OF THE INFILTRATION PHASE OF THE HYDROLOGIC CYCLE.
For summary, see Water Resources Research Catalog, Vol. 4, No. 2.0468.
(h) "The Testing of a Method for Predicting Water Intake into Soils by the Use of Field Cores," R. L. Lambert, Ph.D. thesis, Purdue Univ. Library, 1970.
"The Validity of Soil-Water Diffusivity Theory for Horizontal Water Absorption," D. L. Nofziger, M.S. thesis, Purdue Univ. Library, 1970.
"An Approximate Method for Determining the Hydraulic Conductivity of Unsaturated Soils," R. W. Skaggs, Ph.D. thesis, Purdue Univ. Library, 1970.
- (124W)
DYNAMICS OF WATER INFILTRATION INTO SOIL AS GOVERNED BY SURFACE CRUSTING AND SEALING.
For summary, see Water Resources Research Catalog, Vol. 4, No. 2.0469.

(4679)

FLOW LAWS FOR THE MOVEMENT OF WATER IN SOIL.

- (c) Dr. Dale Swartzendruber.
- (d) Experimental and theoretical; basic research, for doctoral thesis.
- (e) The validity of basic equations for water relationships in porous media and soils, such as Buckingham's capillary potential function, Darcy's proportionality, and the Buckingham-Darcy equation, is being tested in the laboratory under various conditions.
- (f) Discontinued.
- (h) "Comments on 'Determination of the Hydraulic Conductivity of Unsaturated Soils from an Analysis of Transient Flow Data' by Georges Vachaud," D. Swartzendruber, Water Resources Res., Vol. 4, No. 3, pp. 659-660, 1968.
"Fluctuational Variation in the Relationship Between Water Capacity and Soil-Water Suction," J. I. Bazargani and D. Swartzendruber, Israel J. Chem., Vol. 6, No. 3, pp. 357-366, 1968.
"Velocity-Gradient Relationships for Steady-State Unsaturated Flow of Water in Nonswelling Artificial Soils," T. C. Olson and D. Swartzendruber, Soil Sci. Soc. Amer. Proc., Vol. 32, No. 4, pp. 457-462, 1968.

(7586)

MOVEMENT AND RETENTION OF WATER IN SOILS AND POROUS MEDIA.

- (b) Purdue Research Foundation and Office of Water Resources Research, U.S. Dept. of the Interior.
- (c) Dr. Dale Swartzendruber.
- (d) Experimental and theoretical; basic research, for master's and doctoral theses.
- (e) Water flow through both artificial and natural soils is being studied for response to pressure and other types of gradients, as is spontaneous flow against a pressure gradient. Water entry into unsaturated mixtures is being monitored by gamma-ray attenuation, and transducers will also be used if needed. Basic flow equations are being deduced and validated, and are being made the basis for solving boundary-value problems for soil-water transport phenomena, using computer solutions as needed.
- (g) Analysis of gamma-ray-determined transient water contents for water entry into horizontal columns of a silty clay loam soil indicates that the curve of water content versus Boltzmann variable (position coordinate divided by the square root of time) is not invariant with time and position as required by theory. Also, the consistent deviations observed at a low bulk density of 1.08 g/cc were not eliminated by increasing the bulk density to 1.22 g/cc. The applicability of soil-water flow theory is also being studied in experiments with water redistribution and the entry of water through partial hydraulic seals at the inlet end of the soil column. In other experiments with a water-saturated mixture of 5% bentonite clay in 95% sand and silt, water was found to move spontaneously against a pressure head of water, thus corroborating earlier first-time observations of the anomalous behavior.
- (h) "The Flow of Water in Unsaturated Soils," D. Swartzendruber, Chapter 6 in Flow Through Porous Media (R. J. M. DeWiest, ed.), pp. 215-292, Academic Press, New York, 1969.

PURDUE UNIVERSITY, School of Chemical Engineering,
Lafayette, Indiana 47907. Professor Robert A. Greenkorn, Head, School of Chem. Engrg.

(6781)

FLOW REGIMES AND FLOW THROUGH POROUS MEDIA.

- (b) National Science Foundation.
- (d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
- (e) The objective of this research is to determine theoretically and experimentally the flow regimes and their dynamical range for flow in porous media. A creeping flow regime (Darcy's law is valid) is usually assumed for flow in porous media. However, it may be owing to pressure transients or changes in properties of the bed that other flow regimes are present. A first approach to determine flow regimes might be to study the response of fluid filled packed beds to pressure oscillations. Theoretical models such as the wave equation for a viscous fluid in porous media might be used to determine possible regimes.
- (h) "Flow Regimes in Porous Media," P. G. Smith, M.S. thesis, available from Purdue Univ. Library.

(6783)

DISPERSION DURING FLOW IN NON-UNIFORM, HETEROGENEOUS, ANISOTROPIC POROUS MEDIA.

- (b) Federal Water Pollution Control Admin.
- (d) Experimental, theoretical, basic; M.S. and Ph.D. theses.
- (e) The objective of this research is to relate the dispersion tensor to properties of the porous media. We have measured dispersion in heterogeneous linear models and are presently engaged in measuring the effect of non-uniformity and anisotropy on dispersion. These measurements will be made in linear and radial glass bead models. Once the measurements are complete we will relate these data to continuous and statistical theories of the media.
- (h) "A Statistical Model of a Porous Medium With Non-Uniform Pores," R. E. Harring and R. A. Greenkorn, to be published, AIChE J.
"On Dispersion in Laminar Flow Through Porous Media," R. D. Patel and R. A. Greenkorn, to be published, AIChE J.
"Dispersion in Heterogeneous Nonuniform Anisotropic Porous Media," R. A. Greenkorn and D. P. Kessler, Ind. Eng. Chem., 61, No. 9, 14 (1969).
"Dispersion During Flow in Linear Heterogeneous Porous Media," R. C. Pleshek, M.S. thesis, available from Purdue Univ. Library.
"A Study of Permeability and Dispersion Phenomena in an Anisotropic Porous Medium," E. G. Lentz, M.S. thesis, available from Purdue Univ. Library.
"An Experimental Investigation of a Porous Medium Model with Nonuniform Pores," R. J. Pakula, M.S. thesis, available from Purdue Univ. Library.
"Dispersion During Flow in Nonuniform Heterogeneous Porous Media," E. H. Niemann, M.S. thesis, available from Purdue Univ. Library.

(6785)

DISPERSION OF DROPS IN PIPE FLOW OF LIQUIDS.

- (c) J. H. Rushton, Professor.
- (d) Experimental, basic; M.S. and Ph.D. thesis.
- (e) An immiscible liquid is to be injected into a flowing stream of another liquid. Drop size and interfacial area between the phases will be measured by a light transmission technique. Three sizes of main stream tubing are to be used so that different interfacial liquid tensions can be evaluated and other fluid properties varied.

- (h) "Interfacial Area in Pipes Under Continuous, Turbulent Flow Conditions," R. F. Henry, M.S. thesis, available from Purdue Univ. Library.
- (7578)
CONSTITUTIVE EQUATIONS FOR VISCOELASTIC FLUIDS.
(b) National Defense Education Act.
(c) A. H. Emery, Professor.
(d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
- (e) The object is to test the suitability of the various integral constitutive equations now in the literature for fitting the several stresses in transient motions of various kinds. Several developments from this are anticipated: (1) We will develop our own modifications of the equations to do a better job in the transient circumstances (too much emphasis to date has been placed on steady state). (2) Experimental measurements will be made in viscoelastic flows in a cone-and-plate instrument, for the purpose of extending the data and trying to eliminate the serious plate-popping in the Weissenberg instrument. (3) Far in the future, we will get data in non-viscometric flows, where $I_1 = I_2$.
- (h) "A Single-Integral Constitutive Equation," A. H. Emery, Jr., and M. L. White, Trans. Soc. Rheology, 13, 103 (1969). M. L. White, Ph.D. thesis, available from Purdue Univ. Library.
- (7588)
TRANSIENT STRESSES IN COUETTE FLOW.
(c) A. H. Emery, Professor.
(d) Experimental, basic; M.S. thesis.
(e) The object is to measure transient shear and normal stresses in a rotating cylinder viscometer to test the various constitutive equations that describe fluids.
- (7589)
UNIQUENESS OF UNSTABLE FLOW IN POROUS MEDIA.
(d) Experimental, basic; M.S. and Ph.D. thesis.
(e) The objective of this research is to determine uniqueness of unstable flow in porous media to predict rate of finger growth. The equation describing unstable flow will be formulated attempting a minimum energy formulation (using irreversible thermodynamics). The uniqueness will be proven analytically if possible, numerically, and experimentally. Experiments in Hele-Shaw models and porous media models will be used to match theory. The use of an immiscible dispersion coefficient will be considered. If uniqueness is established the rate of fingers growth can be predicted and this can be applied to predicting unstable flow in porous media.
- (h) "An Experimental Study of the Uniqueness of Unstable Flow in Porous Media," S. P. Gupta, M.S. thesis, available from Purdue Univ. Library.
- (7590)
UNSTABLE DISPLACEMENT IN POROUS MEDIA.
(d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
(e) The objective of this project is to describe the motion of the interface between two immiscible fluids flowing in a porous medium. Experiments in monolog and analog models of porous media show the unstable fingers are not unique but are functions of properties of the media and fluids. We are attempting a two-dimensional theory based on these experiments and we eventually wish to describe unstable fingering in these dimensions. It may be necessary to use computer solutions of the equation of condition to solve the problem.
- (h) "Gravity and Viscous Induced Stabilities in Porous Media Displacements," J. E. Varnon, M.S. thesis, available from Purdue Univ. Library.
"Unstable Two-Fluid Flow in a Porous Medium," J. E. Varnon and R. A. Greenkorn, Soc. Petroleum Engrs. J., 3, 293 (1969).
- (7591)
MEASUREMENT OF DISPERSION IN NON-UNIFORM ANISOTROPIC CONSOLIDATED MEDIA.
(b) National Aeronautics and Space Administration.
(c) R. A. Greenkorn, Professor or D. P. Kessler, Assoc. Prof.
(d) Experimental, basic; M.S. thesis.
(e) The objective of this research is to relate the dispersion tensor to properties of the porous media. We have measured dispersion in heterogeneous linear models and are presently engaged in measuring the effect of non-uniformity and anisotropy on dispersion. These measurements will be made in linear and radial glass bead models. Once the measurements are complete we will relate these data to continuous and statistical theories of the media.
- (7592)
DRAG REDUCTION IN TWO-PHASE FLOW.
(c) R. A. Greenkorn or D. P. Kessler (see above).
(d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
(e) The objective is to measure and correlate drag coefficients in tubes, fittings, pumps, etc., in the laminar, transitional, and turbulent regimes for the annular flow of two liquids plus a suspended solid phase. The outer liquid will be viscoelastic. Experiments will be run in flow slip at Reynolds number up to 100,000. Pressure drop measurements, velocity profiles, and visual observations will be used to postulate mechanisms for such flow and derive predicting equations. The data will be correlated according to these equations.
- (7593)
STATISTICAL MODELS OF NON-UNIFORM, ANISOTROPIC POROUS MEDIA.
(c) R. A. Greenkorn, Professor; D. P. Kessler, Assoc. Professor; J. A. Guin, Visiting Asst. Professor.
(d) Theoretical, basic; M.S. and Ph.D. thesis.
(e) The objective of this research is to study and develop meaningful models for non-uniform, anisotropic porous media. These models will be used to study the mechanistic nature of flow in porous media. Attempts to study correlations between various dynamical properties in packed beds requires understanding relationships between media parameters and parameters of the model. The void space in a packed bed may be described parametrically with simplified statistical models. These models help develop more meaningful theories for dispersion during flow through porous media.
- (g) "A Statistical Model for Flow in Nonuniform Anisotropic Porous Media," R. A. Greenkorn and D. P. Kessler, Proc. ASCE-EMD Conf. on Probability Concepts and Methods (1969).
- (7594)
ENERGY TRANSFER IN HIGH TURBULENCE REYNOLDS NUMBER FLOWS EXHIBITING LOCAL ISOTROPY.
(c) R. N. Houze, Assistant Professor.
(d) Theoretical, basic; M.S. and Ph.D. thesis.
(e) Analysis of available experimental data taken in a free turbulent air jet. Analysis allows determination of the three-dimensional energy

spectrum and the energy transfer spectrum from correlation measurements. The various models for energy-transfer spectrum proposed by various investigators will be compared with the measured spectra under conditions where such a comparison is valid and can yield meaningful results.

(7595)

INTERACTION OF INTERFACIAL STRUCTURE WITH GAS PHASE TURBULENCE AND ITS EFFECT ON INTERPHASE TRANSPORT PROCESSES.

- (c) R. N. Houze, Assistant Professor.
- (d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
- (e) Investigation of the interaction of an interfacial structure (shape and motion) with the superposed turbulent gas flow and the effect of this interaction on interphase transport processes in two-phase, gas-liquid systems. Existing models for turbulent gas flow over solid bounding surfaces and compliant surfaces are used to develop a general model for flow over a structured surface. This model is used to examine flow over structured surfaces of varying complexity. Available experimental data are used to check model and provide methods for evaluating necessary parameters.
- (h) "The Effect of a Moving Interface on Gas Phase Turbulence," R. N. Houze and A. E. Dukler, Proc. Symp. on Two Phase Flows, Exeter, England (1965).

(7596)

INTERPHASE TRANSFER.

- (b) National Aeronautics and Space Administration.
- (c) R. N. Houze, Assistant Professor; T. G. Theofanous, Assistant Professor.
- (d) Theoretical, basic; M.S. and Ph.D. thesis.
- (e) Theoretical and experimental investigations on convective diffusion near two-phase interfaces. Curvilinear theory and turbulent models. The fluid mechanics of free interfaces in turbulent flow. Free boundary turbulence. Characterization and application to the convective mechanism of transport of a scalar quantity.

(7597)

COCURRENT GAS LIQUID FLOW IN PACKED BEDS.

- (b) PRF - David Ross Grant.
- (c) D. P. Kessler, Associate Professor.
- (d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
- (e) This is an experimental and theoretical investigation of cocurrent gas liquid flow in packed beds with objectives: (1) characterizing slug length and frequency in the pulse flow regime (therefore determining holdup and, to some extent, interfacial area); (2) developing from (1) a model for delta P; (3) developing a dispersion model for this flow regime; (4) developing a model to describe the instability leading to slugging. Variables include gas and liquid velocities, packing size, type, and configuration, liquid and gas physical properties, and angle at which the body force acts. Data is taken using shorting probes which detect presence of gas or liquid at any given point. This data is recorded on magnetic tape or read out on a strip chart, and then processed to determine the frequency and velocity of slugs of liquid and the correlation of the presence of liquid at one point in the bed with the presence of liquid at some other point in the bed. This work has aimed primarily at defining pulse geometry and velocity. We wish to continue this work to include dispersion effects.
- (h) "Liquid-Gas Distribution Measurements in the

Pulsing Regime of Two-Phase Cocurrent Flow in Packed Beds," W. E. Beimesch, M.S. thesis, available from Purdue Univ. Library in June 1970.

(7598)

MASS TRANSFER IN ANNULAR AND DISPERSED TWO-PHASE FLOW.

- (b) PRF - David Ross Grant.
- (c) D. P. Kessler, Associate Professor.
- (d) Experimental, theoretical, basic; M.S. and Ph.D. thesis.
- (e) In high-velocity cocurrent flow of gas and liquid in a horizontal pipe, two potentially useful flow regimes for mass transfer are dispersed flow and annular flow. Dispersed flow is essentially a spray, while annular flow is a gas phase or spray surrounded by a turbulent annular liquid film. The high degree of turbulence and large interfacial area produce rapid mass transfer. The interfacial area and individual film mass transfer coefficients can be calculated from the data using the Higbie surface renewal theory. Systems of CO₂ and water and CO₂ and NaOH have been studied. CO₂ and monoethanolamine are now being run to compare results, particularly the interfacial area calculations. Future work may be in the area of physical measurement of interfacial area, holdup, and drop size distribution.
- (h) "Mass Transfer in Horizontal Cocurrent Annular Flow," R. L. Davison and D. P. Kessler, presented at 66th Natl. AIChE Meeting, Portland, Oregon, (August 1969).
- "Mass Transfer in Horizontal Cocurrent Annular Flow," R. L. Davison, M.S. thesis, available from Purdue Univ. Library.

(7599)

MEASUREMENT OF DROP SIZES IN FLOWING LIQUID STREAMS.

- (c) J. H. Rushton, Professor.
- (d) Experimental, basic; M.S. thesis.
- (e) A probability study (by means of a computer) of the interference to the passage of light of multiple drops passing through a beam of light, by means of random number distribution of a log-normal size distribution of 100 drops. A study of interference of such drops on light transmission is to be made. From photographic data the actual drop size will be correlated with actual light transmission for calibration, so that actual interfacial areas can be related to the light transmission.
- (h) "Drop Size in Mixing Tanks," P. Graves, M.S. thesis, available from Purdue Univ. Library.

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Dr. J. F. McLaughlin, Head, School of Civil Engrg.

(2841)

HYDROLOGY OF SMALL WATERSHEDS IN INDIANA.

- (b) Purdue Water Resources Research Center (since June 1965); State Highway Dept. of Indiana and Indiana State Flood Control and Water Resources Commission (prior to June 1965).
- (c) Dr. J. W. Delleur.
- (d) Analysis and field investigation; Ph.D. thesis.
- (e) The purpose of the research is to study the hydrology of watersheds less than 300 square miles throughout the State of Indiana to improve the existing methods for estimating the runoff from these watersheds.
- (g) Peak discharges were analyzed statistically and a correlation was obtained between the 25 year peak discharge and geomorphological characteristics.

- tics of the watersheds. Peak discharges for other frequencies may also be obtained. A synthetic design hydrograph was developed on the basis of the instantaneous hydrograph theory. The hydrograph is determined by two parameters which have been related statistically to geomorphological characteristics of the watershed. This study has been extended to include 55 watersheds and approximately 1000 hydrographs. Analysis was made using linear system theory. Fourier, Laplace and direct method of estimating the kernel function was also investigated. Dimensionless kernel functions were grouped according to peak value and base time. Dimensionless kernel may be used to calculate runoff if peak value and base time can be predicted.
- (h) "A Program for Estimating Runoff from Indiana Watersheds - Part I. Linear System Analysis in Surface Hydrology and Its Application to Indiana Watersheds," D. Blank and J. W. Delleur, Tech. Rept. No. 4, Aug. 1968.
- (5111)
FLUIDELASTIC OPERATORS FOR UNDER-STREAMLINED STRUCTURES.
- (b) National Science Foundation.
- (c) Dr. G. H. Toebes.
- (d) Experimental and analytical for M.Sc. and Ph.D. theses.
- (e) Analytical and experimental study aimed at correlating the hydroelastic loading of structural components and the turbulent structure of the generated wake and separating boundary layers; study of energy transfer between fluid and structure.
- (g) Force, displacement and wake turbulence measurements are being made for variety of cylindrical components and plate-like structures. Reduction of data by means of spectrum analysis equipment.
- (h) "The Unsteady Flow and Wake near an Oscillating Cylinder," G. H. Toebes, Trans. ASME, Journ. Basic Eng., pp. 493-505, Vol. 91, No. 3 Series D, Sept. (1969).
- (5831)
PERFORMANCE CHARACTERISTICS OF LARGE SCALE HYDROMECHANICS LABORATORY EQUIPMENT.
- (b) NSF (Traineeship).
- (c) Dr. G. H. Toebes.
- (d) Design, theoretical, experimental; for Ph.D. theses.
- (e) Completed are a 35' x 1.5' x 3' and a 90' x 6' x 3' tilting glass lined flume. The largest flume accommodates sediment recirculation. Under development are a 85' x 30' closed circuit wind tunnel and a 5' x 11' x 150' towing tank.
- (g) Data collection systems for flumes have been completed and are being tested.
- (h) "Research Facilities in Design for Towing-Tank/Wave Basins," C. Akan, M.S. thesis, Purdue Univ., 1967.
- (6197)
INVESTIGATIONS ON FREE SURFACE FLOW AND WAVE PROPAGATION THROUGH CHANNEL-FLOOD PLAIN GEOMETRIES.
- (b) Agricultural Research Service, U.S. Dept. Agriculture.
- (c) Dr. G. H. Toebes.
- (d) Theoretical and experimental; thesis.
- (e) The objectives are to determine improved relationships for energy loss and flood wave velocity for channel-flood plain geometries.
- (g) Several uniform flow energy loss relationships have been determined and reported. Equipment improvement, aimed at processing better detail and measuring dynamic variables, is under way.
- (h) "Uniform Flow in Idealized Channel-Flood Plain Geometries," J. W. Delleur, G. H. Toebes, and B. C. Udeozo, Intl. Assoc. Hyd. Res., Proc. 12th Congr., 1967.
- (6199)
MECHANICS OF SOIL EROSION DUE TO OVERLAND FLOW WITH RAINFALL.
- (b) Agricultural Research Service, U.S. Department of Agriculture.
- (c) Dr. J. W. Delleur and Dr. A. R. Rao, School of Civil Engrg., and Dr. L. D. Meyer, School of Agric. Engrg., Purdue Univ.
- (d) Theoretical and experimental; for Ph.D. thesis.
- (e) Laboratory investigations are being conducted to study overland flow under rainfall. Turbulence characteristics and the flow characteristics such as velocities and depths are being measured and analyzed. The soil erosion due to overland flow will be investigated as the next phase.
- (7600)
STUDIES IN URBAN HYDROLOGY AND THE EFFECTS OF URBANIZATION.
- (b) Indiana Department of Natural Resources, Purdue University, and the Office of Water Resources Research, Dept. of the Interior (July 1966 to June 1969); Purdue University (June 1969 to September 1969).
- (c) Dr. J. W. Delleur and Dr. A. R. Rao.
- (d) The project involves, (1) field investigations, mainly collection of rainfall-runoff data, (2) both basic and applied research in urban hydrology and, (3) work towards M.S. and Ph.D. theses.
- (e) The rainfall-runoff phenomenon is studied using data from watersheds of different degrees of urbanization with a view to study the effects of urbanization on runoff; and to evaluate the existing models and develop methods for prediction of the urban runoff.
- (g) "A Program in Urban Hydrology - Part II. An Evaluation of Rainfall-Runoff Models for Small Urbanized Watersheds and the Effect of Urbanization on Runoff," P. B. S. Sarma, J. W. Delleur, and A. R. Rao, Tech. Rept. No. 9, Water Resources Research Center, Purdue Univ., Lafayette, Ind.
- (7601)
NUMERICAL LABORATORY FOR TWO- AND THREE-DIMENSIONAL TURBULENCE.
- (b) Purdue Research Foundation.
- (c) Dr. Aldo Giorgini.
- (d) Theoretical and numeric-experimental; basic and applied research for Ph.D. theses.
- (e) The numerical simulation is conducted on boundary-free flows of viscous fluids by means of this Fourier-space image. Special numerical techniques are used based on the Fast Fourier Transform and the "Short" convolution. The problems studied include (1) nonlinear hydrodynamic stability, (2) the onset of turbulence, (3) turbulence in boundary free fields, (4) turbulent diffusion.
- (g) A new technique for numerical noncyclic convolution has been discovered. Numerical experiments on two-dimensional turbulence show agreement with some theoretical prediction on the shape of the kinetic energy spectrum.
- (h) "A 'Short' Convolution," Aldo Giorgini and J. R. Travis, Tech. Rept. No. 26, Hydromechanics Lab., School of Civil Engrg., Purdue Univ.
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PURDUE UNIVERSITY, School of Mechanical Engineering, Lafayette, Indiana 47907. Professor P. W. McFadden, Head, School of Mech. Engrg., Professor Robert W. Fox, Head, Fluid Mechanics Laboratory.

(5741)

A STUDY OF ROTATING FLUIDS BETWEEN PARALLEL DISKS.

(c) Dr. E. J. Wellman, Assoc. Prof.

(d) Analytical and experimental; basic research for doctoral thesis.

(e) The system consists of an 18-inch diameter vertical cylindrical tank within which a rotating coaxial circular disk is mounted parallel to the bottom of the tank. Disks of several sizes have been operated at a series of speeds and spacings with the disk rotating in contact with a water surface. Extensive velocity measurements have been made using hydrogen bubbles. Many photographs have been taken of the multiple vortex patterns generated using pearl essence solutions for visualization. The data is presently being analyzed in an effort to develop prediction methods for the flow patterns observed. The study should have application to rotating fluid machinery and also to atmospheric flow conditions.

(g) Stable, rotating, symmetrical vortices have been photographed under various flow conditions with the number of vortices ranging from three to more than thirty. The number of vortices is related to the disk spacing and the Reynolds number. The velocities measured in the vortex-free flow at the lower Reynolds numbers are in good agreement with those obtained from numerical solutions of the equations of motion.

(h) "Instability Phenomenon Associated with an Enclosed Rotating Disk," J. P. Macey and E. J. Wellman, *Physics of Fluids*, Vol. 12, No. 3, pp. 720-722, March 1969.

(7602)

TURBULENT DIFFUSION OF SMALL CONTAMINANTS.

(b) National Science Foundation, and Federal Water Pollution Control Admin.

(c) V. W. Goldschmidt, Assoc. Prof.

(d) Project is both experimental and theoretical in nature. It is leading towards both Master's and Doctoral theses.

(e) Purpose is to evaluate and predict the turbulent transport of contaminants of different sizes carried by a turbulent stream.

(h) "The Hot-Wire Anemometer as an Aerosol Droplet Size Sampler," M. K. Householder and V. W. Goldschmidt, *Atmospheric Environment*, Vol. 3, pp. 643-652, Nov. 1969.

"The Response of a Hot-Wire Anemometer to a Bubble of Air in Water," S. C. Chuang and V. W.

Goldschmidt, *Symp. on Turbulence Measurements in Liquids*, Univ. of Missouri at Rolla, Sept. 1969.

"Turbulent Diffusion and Schmidt Number of Particles," M. K. Householder and V. W. Goldschmidt, *ASCE, J. Engrg. Mech. Div.*, EM6, pp. 1345-1367, Dec. 1969.

"Kinematic Computer Simulation of the Turbulent Dispersion of Neutrally Buoyant Particles," G. Ahmadi and V. W. Goldschmidt, *Developments in Mechanics*, Vol. 5, pp. 201-214, *Proc. 11th Midwestern Mechanics Conf.*, edited by H. J. Weiss, D. P. Young, W. F. Riley and T. R. Rogge, The Iowa State University Press, 1969.

(7603)

WATER TABLE MODELING OF FLUIDIC DEVICES.

(b) Energy Controls Division, Bendix Corporation, South Bend, Indiana.

(c) A. T. McDonald, Assoc. Prof.

(d) Experimental basic research, for Master's thesis.

(e) Modeling of flow in fluidic devices through use of a large-scale free surface water table analog. Purpose is to identify sources of noise and instability in operation, and to obtain data for use in constructing an analytical model of the device.

(g) Facility has been completed and the suitability of the analog verified. Preliminary visual data have indicated one source of noise in the amplifier. Some improvement in operation has been obtained by making changes in configuration based on water table results.

(h) Address inquiries to: Dr. David C. Thoman, Head, Applied Mechanics Group, Energy Controls Division, Bendix Corporation, 717 Bendix Drive, South Bend, Indiana 46620.

THE RAND CORPORATION, Department of Environmental Sciences, 1700 Main Street, Santa Monica, California 90406. Dr. S. M. Greenfield, Department Head.

(6787)

GEOPHYSICAL AND ASTROPHYSICAL FLUID DYNAMICS.

(b) U.S. Air Force, DASA.

(d) Theoretical.

(e) An attempt to understand shock, blast, and impact phenomena through the development and utilization of a suitable hydrodynamic model. The primary application of this research is to the determination of free-field motions and pressures following the detonation of a nuclear device in water or air. Currently directed toward a determination of the equation of state of water over a wide range of pressures and temperatures, and the development and comparison of 2-D time-dependent methods for approximating blast wave interactions with arbitrary, solid boundaries.

(f) Temporarily inactive.

(g) Construction of an e-p-v equation of state for water over a range of variables suitable for nuclear-burst calculations. Development of three time-dependent 2-D hydrocodes.

(h) "Interpolation on a Net of Convex Quadrilaterals," M. Kaplan and R. A. Papetti, *RM-6221-PR*, Feb. 1969.

(6788)

GEOPHYSICS AND ASTROPHYSICAL FLUID DYNAMICS.

(b) Advanced Research Projects Agency, DoD.

(d) Theoretical and numerical; basic and applied.

(e) Development and testing of hydrodynamic models of large-scale ocean circulation. Long-term objective: prediction of oceanic behavior and the dynamics of air/sea interaction as part of the studies of the dynamics of climate.

(g) The time-dependent wind-driven circulation of a homogeneous ocean in basins of various shapes and depths is being studied by numerical integration. The role of the large-scale transient circulations is being given particular attention. An application has been made to the simulation of the circulation of the Atlantic ocean, and work is underway to model the entire world ocean.

(h) "The Effects of Western Coastal Orientation on Rossby-Wave Reflection and the Resulting Large-Scale Oceanic Circulation," *Memo. RM-6110-RC*, The Rand Corporation, 45 pp., August 1969.

(6790)

CLOUD DYNAMICS AND CLOUD PHYSICS.

(b) ARPA, Navy Weather Research Facility.

(c) F. W. Murray.

(d) Theoretical.

- (e) With the ultimate objective of providing inputs for an atmospheric model for weather modification studies, this is an attempt to develop a computer model of a cumulus cloud that follows the growth from the start of convection. Other basic studies include the microphysical effects of cloud-droplet coalescence and other processes.
- (g) Studies have been made of effects of geometry and the nature and size of the initial perturbation. Currently attempts are being made to introduce more microphysics into the dynamic model through parameterization.
- (h) "An Annotated Bibliography of Dynamic Cloud Modeling," F. W. Murray, Rand Memo 5582-ESSA, March 1968. Also a supplement, Rand Memo 5582/1-ESSA, Nov. 1968.
"Numerical Models of a Tropical Cumulus Cloud with Bilateral and Axial Symmetry," F. W. Murray, Rand Memo 5870-ESSA, Nov. 1968.
"Humidity Augmentation as the Initial Impulse in a Numerical Cloud Model," F. W. Murray, Rand Memo 5932-NRL, Jan. 1969.
"Numerical Experiments Pertaining to Warm-Fog Suppression," L. R. Koenig, Rand Memo 6159-PR, Oct. 1969.

(6791)

BIOENGINEERING.

- (d) Theoretical, experimental; applied.
- (e) The study of extra-corporeal systems for oxygenating blood, in cooperation with medical staff of the University of California, Los Angeles. Attempt to find ways of predicting the performance of oxygenating devices for open-heart surgery through fluid-mechanics and mass transfer studies and the testing of experimental devices.
- (f) Completed.
- (g) Simple theory for oxygen transfer to flowing blood in tubes, channels and films has been developed.
- (h) Final report in process.

(6793)

BIOENGINEERING.

- (b) Natl. Insts. of Health.
- (d) Theoretical.
- (e) Study of the fluid mechanics of the human microcirculation. Currently directed toward the development of useful engineering models of flow and transport in the capillaries.
- (g) Analytical model of flow and diffusional transport between red blood cells in a capillary has been developed.
- (h) "Convection and Diffusion in the Microcirculation," J. Aroesty and J. F. Gross, The Rand Corporation RM-6214-NIH (in process), to be published in Microvascular Research.

(6794)

BIOENGINEERING.

- (d) Theoretical; applied.
- (e) An investigation of the complex structure of the eye, attempting to find a more exact relationship among pressures, deformation, and the calibration of pressure-detecting instruments. High pressure is an early sign of glaucoma.
- (f) Completed.
- (g) Ocular tension in the various layers of the cornea due to intraocular pressure are determined as a function of corneal parameter.
- (h) "A Theoretical Model of the Cornea for Use in Studies of Tonometry," C. C. Mow, Bull. Math. Biophysics, 30, pp. 437-453 (1968).

(6795)

DEVELOPMENT OF WATER QUALITY SIMULATION MODEL.

- (b) City of New York.
- (d) Applied.
- (e) The objective is to develop a computational model for the flow in estuaries and coastal seas, combined with a model for the advective and diffusive transport of pollutants, which also permits simulation of reactions of pollution substances.
- (g) The model for the flow and the advective and diffusive transport of pollutants in well-mixed waters has been developed and is being evaluated for Jamaica Bay, New York. The two-dimensional model includes flow over tidal flats which may become exposed during ebb. Results are presented in graphs and charts with isocontours of concentrations. The model is being used in support of the extent and control of pollutants in the Bay.
- (h) "A Water Quality Simulation Model for Well-Mixed Estuaries and Coastal Seas: Vol. I, Principles of Computation," Y. Y. Leendertse, RM-6230-RC, The Rand Corporation, Feb. 1970.

RENSELAER POLYTECHNIC INSTITUTE, Department of Mathematics, Troy, New York 12181. Dr. George H.

Handelman, Department Chairman.

(6772)

STABILITY OF VISCOUS FLOW OVER CURVED SURFACES.

- (b) Office of Naval Research.
- (c) Professors R. C. DiPrima, and L. A. Segel.
- (d) Theoretical; basic research.
- (e) Development and breakdown of Taylor-vortex flow and Bénard cells are studied as prototypes of flows in which nonlinear stability effects are important.
- (g) Nonlinear stability theory for horizontally unbounded layers heated from below has been extended so that it applies to shallow layers with vertical boundaries. Non-axisymmetric vortical motion has been considered in a nonlinear analysis of flow between counter-rotating concentric cylinders. For a class of fluid stability problems, a major analysis has been made of the nonlinear mechanism by which a flow of a single wavenumber may (or may not) emerge from an initially multi-modal flow. Also see (6773).
- (h) "Distant Side-walls Cause Slow Amplitude Modulation of Cellular Convection," L. A. Segel, J. Fluid Mech. 39, 203-224, 1969.
"On the Effects of Sidewalls in Cellular Convection," L. A. Segel, to appear in Proc. IUTAM Symp. on Instability of Continuous Systems, Sept. 1969, Herrenalb, Germany, published by Springer-Verlag.
"A Nonlinear Investigation of the Stability of Flow Between Counter-Rotating Cylinders," R. C. DiPrima and R. N. Grannick, to appear in Proc. IUTAM Symp. on Instability (see above).
"Stability of Spatially Periodic Supercritical Flows in Hydrodynamics," S. Kogelman and R. C. DiPrima, Phys. Fluids, to appear.
"Nonlinear Wave-number Interaction in Near-critical Two-dimensional Flows," R. C. DiPrima, L. A. Segel, W. Eckhaus, Report submitted for publication. Request from authors.

(6773)

NONLINEAR EFFECTS IN HYDRODYNAMIC AND THERMAL INSTABILITY PROBLEMS.

- (b) U.S. Army Research Office - Durham.
- (c) Professors R. C. DiPrima and L. A. Segel.
- (d) Theoretical; basic research.

- (e) Wavenumber selection and pattern formation are studied numerically and analytically to provide basic understanding of nonlinear flow processes.
- (g) Calculations have been made of the nonlinear effects of surface curvature and fluid property variations in cellular convection in a layer of fluid heated from below. A critical survey has been made of computing methods which have been used in nonlinear hydrodynamic stability theory. Certain expansions used in this theory have been rigorously justified. A combination series-expansion finite difference approach has been applied to the study of vortices between concentric rotating cylinders. Nonlinear wave-number selection calculations have been reviewed. Also see (6772).
- (h) "Effects of Surface Curvature and Property Variations on Cellular Convection," S. H. Davis and L. A. Segel, *Phys. Fluids*, **11**, 470-476, 1968. "Computing Problems in Nonlinear Hydrodynamic Stability," R. C. DiPrima and E. H. Rogers, *Phys. Fluids*, Supplement II, **12**, No. 12, Part II, 1969. "Completeness Theorem for Non-selfadjoint Eigenvalue Problems in Hydrodynamic Stability," *Arch. Rat. Mech. Anal.* **34**, 218-227, 1969. "A Numerical Study of Wide-Gap Taylor Vortices," E. H. Rogers and D. W. Beard, *J. Comp. Phys.* **4**, 1-18, 1969. "On the Stability of Periodic Solutions in Fluid Mechanics," W. Eckhaus, to appear in Proc. IUTAM Symp. Instability of Continuous Systems, Herrenalb, Germany, Sept. 1969, published by Springer Verlag.

UNIVERSITY OF RHODE ISLAND, Graduate School of Oceanography, Narragansett Marine Laboratory, Kingston, Rhode Island 02881. Dr. John A. Knauss, Dean of School.

(6220)

INTERNAL WAVES AND TURBULENCE.

- (b) U.S. Coast Guard Oceanographic Unit.
- (c) Dr. Kern Kenyon, Narragansett Marine Lab., and Dr. John E. Spence, Dept. of Ocean Engrg.
- (d) Theoretical and field investigation; basic research for M.S. thesis.
- (e) To measure and explain coherence of temperature records obtained from vertically separated sensors in shallow ocean depths.
- (f) Active, nearing completion.
- (g) For a given frequency the coherence between two temperature records is observed to decrease with increasing vertical separation, and for a given vertical separation the coherence decreases with increasing frequency. Attempts to explain these observations in terms of simple theories have met with limited success.
- (h) "Report on Oceanographic Data Analysis and Interpretation and the Evaluation of Existing and Proposed Oceanographic Data Systems - II," C. Beckers, A. Bhopale, J. Osuna, and J. E. Spence, Tech. Rept. Div. of Engrg. Research and Development, Univ. of Rhode Island, Feb., 1970.

ROBERT TAGGART INCORPORATED, Marine Research, 3930 Walnut Street, Fairfax, Virginia 22030. Robert Taggart, President.

(6262)

THE WALL PRESSURE SPECTRA IN A THICK TURBULENT BOUNDARY LAYER.

- (b) Office of Naval Research, Dept. of the Navy.

- (c) Mr. Matthew Stevenson, Hydrodynamicist.
- (d) Experimental; applied research.
- (e) Tests were carried out with 1/8" diameter pressure transducers flush-mounted in the wall of a quiet flow water tunnel in which the boundary layer was approximately 3" thick. The maximum flow velocity was varied between 12 and 22 feet/second.
- (f) Completed.
- (g) From spectrum levels it is shown that for increasing frequency, the level falls at a rate of 10 db/octave and for any frequency the dependence on velocity is about 2 db/foot per second. Qualitatively, the low frequency results show a tendency for spectral density values to decrease with decreasing frequency. At high frequencies the small wavelength components of the pressure field cannot be properly resolved by the finite sized transducers. An average value of the ratio of root-mean-square pressure to dynamic pressure is found to be 5.2×10^{-3} for a zero-sized transducer. In the higher frequency range the data are better represented by scaling the spectral density using wall shear stress and transducer size rather than dynamic pressure and displacement thickness.
- (h) "The Wall Pressure Spectra in a Thick Turbulent Boundary Layer," Final Report RT-15101 to the Acoustics Branch, Office of Naval Research, under Contract Nonr-4791(00).

ROCKY MOUNTAIN HYDRAULIC LABORATORY, Allenspark, Colorado 80510. Professor C. J. Posey, Director. (Winter Address: Dept. of Civil Engrg., U. of Connecticut, Storrs, Connecticut 06268.)

(6377)

HOW TO PLACE ROCK SAUSAGES TO OBTAIN EFFECTIVE EROSION PROOFING.

- (b) Water Resources Inst., Univ. of Connecticut.
- (c) Experimental; development or applied research.
- (e) This phase of a Water Resources Inst. project was undertaken to develop criteria for fail-safe installation of rock sausages.
- (f) Suspended.
- (g) Tests show that rock sausages must be placed tightly together parallel to the direction of flow, over reverse filter layers meeting the Terzaghi-Vicksburg specifications.
- (h) "Erosion Protection," 30-minute 16 mm silent film, available at \$1.00 rental charge from Audiovisual Dept., Univ. of Connecticut, Storrs, Conn., 06268.

RUTGERS UNIVERSITY, The State University of New Jersey, College of Engineering, Department of Mechanical and Aerospace Engineering, New Brunswick, New Jersey 08903. Dr. R. H. Page, Department Chairman.

(125W)

LAWS OF DISPERSION.

- (d) A study of turbulent dispersion of heavy particles and bubbles relative to problems in water pollution dispersion. Refer to WRRC for details.

(7609)

SECOND-ORDER UNSTEADY SUBCAVITATING HYDROFOIL THEORY.

- (b) Naval Ship Research and Development Center.
- (c) Prof. C. F. Chen.
- (d) Theoretical; applied research.
- (e) The purpose of the project is to develop a theoretical method to calculate the hydrodynamic forces on an oscillating hydrofoil to a higher

- degree of accuracy than the linear theory.
- (f) Completed.
 - (g) A second-order theory for the lifting problem has been developed for foils performing harmonic oscillations either in plunging or pitching modes. The second-order problem is obtained by systematic expansions of the variables involved. By a suitable definition of the second-order acceleration potential, the second-order problem is reduced to a form similar to that of the first-order problem. The method used for the first-order problem has been applied for the solution of the second-order problem with some modifications. Numerical results have been obtained for a symmetric Joukowski foil oscillating in plunging or pitching mode. These results are compared with existing results on the effect of finite thickness of the foil, and to some recent results obtained by numerically solving the full nonlinear problem.
 - (h) "Second-Order Theory for Flow Past Oscillating Foils," C. F. Chen and Richard A. Wirtz, AIAA J., Vol. 6, No. 8, pp. 1556-1562, Aug. 1968.
- (7610)
VORTEX SHEDDING FROM CIRCULAR CYLINDERS IN SHEARED FLOW.
- (c) Prof. C. F. Chen.
 - (d) Experimental; basic research; Master's thesis.
 - (e) The effect of flow shear on the shedding frequency of vortices from cylinders is studied experimentally.
 - (f) Completed.
 - (g) It is found that for a moderate shear parameter, the relationship between local Strouhal number and the local Reynolds number is the same as that for uniform flow recommended by Roshko.
 - (h) "Vortex Shedding from Circular Cylinders in Sheared Flow," C. F. Chen and Bruce J. Mangione, AIAA J., Vol. 7, No. 6, pp. 1211-1212, June 1969.
- (7611)
STUDIES IN STRATIFIED FLUIDS.
- (b) National Science Foundation.
 - (c) Prof. C. F. Chen.
 - (d) Experimental and theoretical; basic research, doctoral thesis.
 - (e) Two problems have been studied. The first is the lee wave system generated by the motion of a body in a stratified fluid. The second is the effect of density stratification on the stability of flow generated by a rotating cylinder.
 - (f) Completed.
 - (g) 1. The flow of a density-stratified fluid about symmetric towed bodies was investigated both experimentally and theoretically. A theoretical investigation was made using an inverse method of solution in which the bodies are generated by distributions of doublets of varying strength and location within the flow field. It was found that good agreement was obtained between the theory and experiment as long as the model was towed at a symmetric plane of the channel. At other planes of towing, the quantitative agreement between theory and experiment was not good. 2. The effect of a linear density gradient on the stability of the time-dependent flow induced by an impulsively started cylinder with horizontal axis of rotation was experimentally investigated along with the effect of the instabilities on the flow far from the cylinder. It was observed that the density gradient serves to inhibit the formation of the Taylor instabilities and alters their shape from circular to elliptical. A strong Richardson number dependence for stability was exhibited in stratified fluids. The axial spacing of the instabilities was not observed to be affected by the presence of a density gradient.
 - (h) "Studies in Stratified Flow," John V. Droughton, Ph.D. thesis, Dept. of Mech. and Aerospace Engrg., Rutgers Univ., Oct. 1969.
- (7612)
BOUNDARY LAYER IN OSCILLATING FLOW.
- (b) Air Force Office of Scientific Research.
 - (c) Prof. C. F. Chen.
 - (d) Experimental; basic research; Ph.D. thesis.
 - (e) The characteristics of laminar boundary layer under oscillating flow are investigated experimentally.
 - (f) Completed.
 - (g) The response of the laminar skin friction in the presence of a sinusoidal free stream velocity has been experimentally investigated. The case of large velocity amplitude variation (50% about a 30 ft/sec mean) at low frequency (1 Hz) was considered. The flow was monitored by two constant-temperature hot-wires, one in the freestream and one in the boundary layer. The boundary layer hot-wire was used to measure steady and non-steady boundary layer velocity profiles in which good agreement with the literature was demonstrated. It was also calibrated to measure dynamic skin friction. The periodic skin friction data verified existing laminar theories; however, the theories overpredicted the skin friction amplitude when the freestream experienced a large amplitude of 50%.
 - (h) "Experimental Investigation of Laminar Skin Friction under Oscillating Flow," James B. Caldwell, Dept. of Mech. and Aerospace Engrg., Rutgers Univ., Oct. 1969.
- (7613)
STABILITY OF TIME-DEPENDENT ROTATIONAL FLOW.
- (b) National Science Foundation.
 - (c) Prof. C. F. Chen.
 - (d) Experimental and theoretical; basic research; Ph.D. thesis.
 - (e) The purpose of this project is to study both experimentally and theoretically the stability of a basically time-dependent flow. In order to accomplish the objective simply and with some degree of accuracy, a rotating Couette flow is studied.
 - (g) For a Couette flow with a radius ratio of 0.1, the critical time for the onset of instabilities has been determined experimentally. A quasi-steady, linear perturbation analysis has been applied to predict the critical time with qualified success. Theoretical analyses are underway (1) to use the initial value approach to the problem, and (2) to numerically integrate the Navier-Stokes equation for the flow region to detect the onset of instability.
 - (h) "The Stability of Viscous Time-Dependent Flow Between Concentric Rotating Cylinders with a Wide-Gap," Robert P. Kirchner, Ph.D. thesis, Dept. of Mech. and Aerospace Engrg., Rutgers Univ., Oct. 1968.
 - "The Stability of Time-Dependent Rotational Couette Flow. Part I. Experimental Investigation," R. P. Kirchner and C. F. Chen, J. Fluid Mech., Vol. 40, Part 1, pp. 39-48, Jan. 1970.
- (7614)
NUMERICAL METHODS FOR FREE SHEAR LAYER PROBLEMS.
- (b) Air Force Office of Scientific Research.
 - (c) Asst. Prof. R. Elassar.
 - (d) Theoretical; applied research.
 - (e) Numerical solutions of laminar and turbulent

- flows associated with wakes and base flow problems are obtained by finite difference methods. Coordinate transformations which lead to computationally efficient schemes are being investigated.
- (g) A linear multi-level finite difference scheme has been applied to solve free mixing flow problems.
 - (h) "Incompressible Turbulent Wake of a Flat Plate," R. J. Elassar and R. H. Page, AIAA J., Vol. 7, No. 7, pp. 1388-1389, July 1969.
- "Compressible Laminar Wake of a Thin Flat Plate," R. J. Elassar, ASME Paper No. 69-WA/FE-6, Dec. 1969.
- (7615)
MECHANISMS OF EROSION OF DUCTILE METALS BY SOLID IMPINGEMENT.
- (b) Atomic Energy Commission.
 - (c) Professor Mark B. Moore.
 - (d) Experimental; basic research.
 - (e) A study of the basic erosion processes which take place when ductile metal surfaces are exposed to solid particle impingement.
 - (f) Completed.
 - (g) Three separate modes of erosion were identified, and the mechanisms of each were studied. Material loss rates were correlated with erosion mode, energy transfer rates, and particle size and velocity. A marked similarity between the erosive action and wave formation on a liquid surface was noted.
 - (h) Twelve documents have been presented to the Atomic Energy Commission, sponsors of the project. These may be obtained by reference to : Atomic Energy Commission, Contract AT (30-1) 3477, Documents No. NYO-3477, (1-12).
- (7616)
SEPARATED FLOWS.
- (b) Air Force Office of Scientific Research.
 - (c) Professor R. H. Page.
 - (d) Experimental and theoretical basic research.
 - (e) Basic research in separated flows is being carried out to determine a much more fundamental understanding of the thermodynamic and dynamic mechanisms.
 - (g) Special experimental research facilities have been developed and theoretical models of various separated or separating flows have been formulated.
 - (h) "Annual Report - Separated Flows, 1968 to 1969," R. H. Page, AFOSR 69-2159TR, available from DDC.
- (7617)
FLOW REATTACHMENT.
- (b) Air Force Office of Scientific Research.
 - (c) Professor R. H. Page.
 - (d) Experimental and theoretical basic research.
 - (e) A study of the reattachment of a separated flow to a wall.
 - (g) Theoretical modeling has agreed with the experimental data.
 - (h) "Supersonic Turbulent Flow Reattachment Downstream of a Two-Dimensional Backstep," D. C. Reda and R. H. Page, AFOSR 69-1592 TR, available from DDC.
- (7618)
EMIL BUEHLER WIND TUNNEL.
- (b) Emil Buehler Corporation, Incorporated.
 - (c) Professor R. H. Page.
 - (d) Design; development.
 - (e) Design, operation, and development, of a supersonic variable Mach number wind tunnel and auxiliary apparatus for teaching and research programs. A variable Mach number wind tunnel (up to
- Mach 4.0) has been used extensively since it was first operated on April 21, 1964. It is used for teaching and research programs.
- (g) Improvements in the tunnel's operation have been continuously made.
 - (h) "The Theory and Operation of the Emil Buehler Supersonic Wind Tunnel," C. P. Sarkos, Master's thesis, Rutgers Univ., June 1965.
- (7619)
FLUIDICS RESEARCH.
- (c) Professor R. H. Page.
 - (d) Theoretical investigations.
 - (e) Theoretical analyses of separating and reattaching flows are being carried out.
 - (g) Basic fluid mechanics of supersonic separation and reattachment for fluidic devices has been formulated.
 - (h) "Fluid Mechanics of Supersonic Separation and Reattachment," R. H. Page, Proc., IFAC Symp. Proc. on Fluidics, London, Nov. 1968.
- (7620)
STUDIES IN LAGRANGIAN TURBULENT DISPERSION.
- (b) Department of Defense.
 - (c) Prof. R. L. Peskin.
 - (d) Theoretical; basic research; doctoral thesis. (Subproject under "Dissemination Processes Project.")
 - (e) The Langevin Model for study of Lagrangian turbulence was examined and modified to account for necessary viscous effects as well as non-stationarity to simulate the true nonlinear nature of the full Lagrangian equations. Single and two-point particle dispersion was studied. The necessary conditions for complete stationarity were established so that the Langevin equation could reproduce G. I. Taylor's single-point diffusion equation. Conditions for validity of Richardson's Law were examined under this model and the law was shown to be valid over certain time regions, Reynolds number conditions and under certain conditions of initial separation. The theory of C. C. Lin was put in perspective and shown to be consistent for high Reynolds numbers. Information relating Eulerian and Lagrangian parameters was attained using the theory. Results were applied to the Corrsin, Uberoi data for diffusion in grid turbulence and the model was also applied to the study of dispersion in shear flow. In the latter case, the expressions for dispersion rates in the intermediate time region were obtained.
 - (f) Completed.
 - (g) See (e).
 - (h) "The Langevin Model for Turbulent Diffusion," E. L. Krasnoff and R. L. Peskin, Ph.D. thesis, Rutgers Univ., 1970, to be published in Geophysical Fluid Dynamics.
- (7621)
THE TURBULENT WAKE OF AN AXISYMMETRIC BODY AT SUBSONIC SPEEDS.
- (b) Air Force Office of Scientific Research.
 - (c) Asst. Prof. C. E. G. Przirembel.
 - (d) Experimental, theoretical; basic research.
 - (e) The near-wake of an axisymmetric body, which is immersed in a uniform subsonic flow field, is under extensive experimental and theoretical investigation. The present experimental model is a circular cylinder aligned with the free stream direction. The base of the model is blunt, so that the separation line of the approaching boundary layer is fixed at a known location. Fundamental understanding of this near-wake flow field is necessary for the prediction of base drag, base

heat transfer, and the configuration of the related far wake. For example, this type of flow field is associated with the motion of such diverse objects as missiles, aircrafts, buses, and flowmeter elements.

- (g) A special low turbulence wind tunnel with a closed jet test section is being used for the experimental program. The model support system has been designed to eliminate any support interference effects on the free stream and the approaching boundary layer. Detailed pressure measurements were made in all regions of the near-wake, as well as in the approaching flow and on the body surface. The flow field was found to be quite insensitive to changes in the free stream Mach number ($0.14 \leq M_\infty \leq 0.30$) with respect to the base pressure coefficient and the location of the rear stagnation point. The influence of the separation processes was found to extend approximately two base diameters upstream on the body. The dividing streamline was nearly elliptical in shape. Extensive comparison of the present data and that of other authors with the two available subsonic wake theories showed reasonable agreement for the base pressure but substantial scatter for the length of the recirculation region.
- (h) "Subsonic Axisymmetric Near Wake Studies," K. J. Oswandel, M.S. thesis, May 1969.
 "The Near-Wake of a Blunt Based Axisymmetric Body at Mach 0.14," D. P. McErlean, Ph.D. thesis, December 1969.
 "The Turbulent Near-Wake of an Axisymmetric Body at Subsonic Speeds," D. P. McErlean, C. E. G. Przirembel, Dept. of Mech. and Aerospace Engrg., Rutgers Univ., RU-TR 132-MAE-F, Feb. 1970.
 "An Experimental Study of the Subsonic Turbulent Boundary Layer Approaching an Axisymmetric Blunt Base," C. H. Yi, M. Phil. thesis, April 1970.

SACRAMENTO STATE COLLEGE, School of Engineering, Department of Civil Engineering, Sacramento, California 95819. Howard L. Hartman, Dean, School of Engrg.

(7622)

COMPLEMENTARY - COMPETITIVE ASPECTS OF WATER STORAGE.

- (b) Federal Water Pollution Control Admin.
- (c) Dr. Kenneth D. Kerri.
- (d) Experimental and field; applied research.
- (e) Allocation of water for flow augmentation to enhance water quality and other beneficial uses conflicts with other water demands. An analytical model was developed that was capable of allocating water to competing demands on the basis of economic efficiency. An algorithm based on the theory of marginal analysis allocates water after considering the complementary and competitive uses of available water. Allocation decisions may be reached and then revised throughout the demand period regarding the amount of water to remain in storage or to be stored and then released for downstream uses or downstream diversions. Results indicate the frequency and magnitude of any shortages for each use of water. Simulation of the hydrologic and economic systems of a river basin verified the effectiveness of the analytical model.
- (f) Completed.
- (g) An analytical model was developed and tested that is capable of indicating the extent and magnitude of the complementary and competitive aspects of water storage for water quality control.
 A daily streamflow simulator was developed and tested which generates daily nonhistoric flow sequences with statistical properties and hydro-

graphs similar to historical flows. A definite relation was developed regarding the influence of reservoir operation on recreational attendance for the area studied.

A water quality response surface was drawn from the results of the hydrologic and economic simulation model showing the maximum net benefit contours for water quality combinations of a DO of 4, 5, and 7 mg/l and coliform bacteria MPN's of 240, 1000, 2400, and 5000 per 100 ml.

Flow augmentation, as shown by this research project, is an economically feasible means of achieving and maintaining water quality objectives. The effectiveness is a function of the shape of the hydrograph, the cost of alternative means of waste treatment, and the value of the complementary and competitive uses of the available water. Reliability of flow augmentation is a function of other project purposes and other storage facilities in the basin. Directly downstream of a reservoir, annual demands should be met or almost met every year. In a large, highly regulated system with many reservoirs where demands for the release of water for flow augmentation may occur only during water short years, a new system may not be too reliable.

Storage of water for temperature control accompanied by selective withdrawal competes with demands for flow augmentation. Frequency and magnitude of shortages in the minimum conservation pool (target temperatures) should be similar to shortages in downstream flows. Available water for fisheries should be allocated between both demands for flow and temperature target objectives. The sacrifice of either objective for the other could cause considerable losses even though one of the objectives was achieved.

Small, frequent shortages will be encountered by water users and occasional damages from floods will be encountered when economic efficiency is the objective if structural inputs are sized, target outputs are selected, and operational procedures are established on the basis of economic simulation models or mathematical optimization techniques.

- (h) "Tolerable Shortages in Irrigation System Design," D. J. Hinrichs, presented at Pacific Southwest Conf. ASCE Student Chapters, San Francisco, Calif., 1969. Submitted to J. Irrigation and Drainage Division, ASCE.
 "Allocation of Water for Flow Augmentation," K. D. Kerri, presented at 1969 Water Pollution Control Fed. Conf., Dallas, Texas, Oct. 1969. Submitted to J. Water Poll. Control Fed.
 "Application of Industrial Dynamics to Water Quality Control," K. D. Kerri, Industrial Dynamics Newsletter, MIT, May 1968.
 "Daily Streamflow Simulation," K. Payne, W. R. Neuman and K. D. Kerri, J. Hydraulics Div., ASCE, Vol. 95, No. HY4, Proc. Paper 6665, July, 1969, pp. 1163-1179.
 "Complementary - Competitive Aspects of Water Storage," K. D. Kerri, (Final Report) Sacramento State College, for Federal Water Pollution Control Admin., 1969.

(7623)
 THE ECONOMIC VALUE OF PROBABILITY RELATED TO HYDROLOGIC FORECASTING.

- (c) Dr. Murland R. Packer.
- (d) Theoretical; applied research.
- (e) Water resources forecasting has been developed to provide advance information on the estimated amount of runoff which can be expected in the future. Such information can be valuable in

guiding the operations of reservoirs and of reservoir systems. In order to calculate the economic benefit of water resources forecasts, the proposed research will study the methodology by which the probability of forecast error can be related to economic benefits.

(7624)

FLOODPLAIN ORCHARD MODEL STUDY.

- (b) State of California Reclamation Board.
- (c) Dr. Alan L. Prasuhn or Prof. William R. Neuman.
- (d) Experimental; applied research.
- (e) A model study was conducted of overbank flood flows through orchards planted along the Sacramento and Feather Rivers on the river side of the levees. The existing tree configuration required by the California Reclamation Board was compared to a hedgerow configuration proposed by the orchardists. Nonalignment of the flow with the tree rows and flow depth relative to tree height were also studied. Model trees consisting of pipe cleaners twisted together were compared in individual drag tests to a carefully scaled model pear tree.
- (f) Completed.
- (g) It was found that if the design flood flow was above the tree tops only a small increase in resistance and therefore depth could be expected with the new tree configuration. If the maximum flow was to be within the tree limits very large increases in resistance and depth could occur. Manning's n was found to increase continuously with depth within the tree height. Above the trees n decreased with increasing depth. The model was verified by comparison with historic backwater computations on the two rivers.
- (h) "Proposed Orchard Standards," Report to California Reclamation Board, April 1969. Technical paper in progress.

(7625)

RELATIONSHIPS OF SEDIMENT TRANSPORT TO BED FORMS AND TURBULENCE LEVELS.

- (c) Dr. Alan L. Prasuhn
- (d) Experimental; basic research.
- (e) Turbulence measurements are attempted in sediment flows in order to get better experimental evidence of the role of turbulence in sediment transport.

ST. ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA, Mississippi River at Third Avenue, S. E., Minneapolis, Minnesota 55414. Dr. Edward Silberman, Director.

Inquiries concerning Projects 3824, 4209, 5500, 5792, 5795, 5796, 5799, 6735, 6736, 3738-6747, 6749-6751, 7661-7676 should be addressed to the Director, St. Anthony Falls Hydraulic Laboratory, at the above address.

Inquiries concerning Projects 111, 1168, 2386, 7677 should be addressed to Mr. Fred W. Blaisdell, Research Investigations Leader, Soil and Water Conservation Research Division, Agricultural Research Service, St. Anthony Falls Hydraulic Laboratory, at the above address.

Inquiries concerning Project 194, which is conducted in cooperation with the Corps of Engineers and the U.S. Geological Survey, should be addressed to Engineer in Charge, Mr. John V. Skinner, Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory, at the above address.

(111)

CLOSED CONDUIT SPILLWAY

- (b) Agricultural Research Service, U.S. Dept. of Agric., in cooperation with the Minnesota Agric. Expt. Sta. and the St. Anthony Falls Hydraulic Lab.
- (d) Experimental; generalized applied research for development and design.
- (e) A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet. The elbow and transition between the two-way drop inlet and the barrel is being studied to determine the pressures and the best form to minimize the possibility of cavitation.
- (g) The theory of closed conduit spillways has been developed, verified, and published. Results of tests on many forms of the closed conduit spillway entrance have been published. Pipe culverts laid on steep slopes may flow completely full even though the outlet discharges freely. Generalized methods for analysis and reporting of the results have been developed. The use of air as the model fluid has been verified by comparing test results with those obtained using water as the model fluid. The two-way drop inlet with the horizontal anti-vortex device causes the spillway to act as a self-regulating siphon when the headpool level approximates the anti-vortex plate elevation. The height of the anti-vortex plate above the drop inlet crest and the overhang of the anti-vortex plate determine the effectiveness of the plate as an anti-vortex device. For one form of the inlet, tests have been made to determine the crest loss coefficient, the barrel entrance loss coefficient, the pressures on the plate and the drop inlet, the general performance of the inlet, minimum and maximum permissible plate heights, and the head-discharge relationship for plate control. Variables have been the length of the drop inlet, the barrel slope, the height and overhang of the anti-vortex plate, and the sidewall thickness. Tests of low-stage orifices in the two-way drop inlet have shown that improper location and improper proportioning of the orifices can prevent priming of the spillway. The proper location and size of the orifices have been determined. To supplement the experiments, potential flow methods have been used to determine the theoretical coefficient of energy loss at the crest of the two-way drop inlet. Six shapes of elbow between the two-way drop inlet and the transition were tested. The elbows were evaluated on the basis of high minimum relative pressures and the presence of adverse pressure gradients. The theoretical free streamline elbow had small areas of adverse pressure gradient. The best elbow is an ellipse with semi-major and semi-minor axes of 2D and 1D. (D is the barrel diameter.) An elbow made up to two 45-degree circular segments of radii D/2 and 3D/2 also has generally satisfactory hydraulic characteristics. Seven transitions between the half-square crown -- half-circular invert cross section at the elbow exit and the circular barrel were tested. The best transition is warped and 1D long. (See 1968 issue for details -- ed.) The entrance loss coefficients are low and identical within the limits of experimental precision for all elbow-transition combinations. Tests on the hood drop inlet have shown that the

hood barrel entrance can be used to reduce the minimum required height of the drop inlet. Minimum sizes of drop inlet and anti-vortex devices have been determined.

- (h) "Crest Losses for Two-Way Drop Inlet," George G. Hebaus, ASCE, J. Hyd. Div., Vol. 95, No. HY3, pp. 919-940, May 1969.

(1168)

A STUDY OF CANTILEVERED OUTLETS.

- (b) Agricultural Research Service, U.S. Dept. of Agric. in cooperation with Minnesota Agric. Expt. Sta. and St. Anthony Falls Hydraulic Lab.
- (d) Experimental; generalized applied research for design.
- (e) Pipe outlet conduits for small spillways are frequently cantilevered beyond the toe of the earth dam. Attempts are being made to determine quantitatively the size of the scour hole to be expected under various field conditions. Rectangular cantilever outlets with a deflector at the exit to throw the water away from the structure and move the scour hole further downstream are also scheduled for investigation.

(2386)

GENERALIZED DESIGN OF TRANSITIONS FOR SUPERCRITICAL VELOCITIES.

- (b) Agricultural Research Service, U.S. Dept. of Agric., in cooperation with the Minnesota Agric. Expt. Sta. and the St. Anthony Falls Hydraulic Lab.
- (d) Experimental; generalized applied research for development and design.
- (e) Studies have been made to develop a transition and to determine the rules for its design. The transition is used to change the flow cross section from circular to rectangular when the velocities are supercritical.
- (f) Completed.
- (g) When the flow cross section is changed abruptly from a circular pipe to a rectangular open channel the rectangular channel width must be $1.0D$, where D is the pipe diameter, to prevent excessively high waves and disturbances in the rectangular channel. To provide space for the pipe to expand, an expansion section wider than the outside diameter of the pipe and not longer than $0.5D$ can be used between the pipe and the rectangular channel. The channel floor can be lowered below the pipe invert to accommodate pipe expansion and permit drainage of the expansion section. Although there is a diamond-shaped wave pattern with waves of significant height in the $1.0D$ -wide channel, the transition performance is generally satisfactory at all discharges between $Q/D^{5/2} = 4$ and 20 .
- (h) "Abrupt Transition from a Circular Pipe to a Rectangular Open Channel," Fred W. Blaisdell, Charles A. Donnelly and Kesavarao Yalamanchili, St. Anthony Falls Hydr. Lab. Tech Paper No. 53, Ser. B., 67 pp., July 1969.

(3824)

SURFACE CHARACTERISTICS OF AIR ENTRAINMENT FLOW IN STEEP CHANNELS.

- (d) Analytical, experimental; Ph.D. thesis.
- (e) Analytical and experimental investigation of the air concentration, velocity distribution, and surface roughness of water flow in steep open channels. Experimental investigation was carried out on the SAF high velocity channel for slopes up to 53 degrees. Velocities were measured by means of a pitot tube and high speed photography. Air concentration was measured by the SAF concen-

tration meter. The surface elevation was measured by a device which measures the average time the surface is above a given elevation.

(f) Completed.

- (h) "Surface Characteristics of Self Aerated Flow in Steep Channels," J. M. Killen, Ph.D. thesis, July 1968.

(4209)

THE INFLUENCE OF ELECTROKINETIC PHENOMENA ON THE HYDRAULIC AND ELECTROSMOTIC PERMEABILITY OF UNIFORM VERY FINE SANDS.

- (d) Experimental and theoretical; Ph.D. thesis.
- (e) Accurately sized, narrow range, angular quartz particles and spherical glass beads were tightly placed in a permeameter with reversible silver-silver chloride electrodes at the ends of the test section. Streaming potential, streaming current, electrical resistivity of low conductivity liquid, and filter velocity were precisely measured. Studies include: (1) flow retardation from return electroosmosis; (2) analysis of electrosmotic permeability factors with respect to particle characteristics and hydraulic permeability, and (3) comparisons of streaming current and filter velocity at varying Reynolds numbers.
- (f) Completed.
- (g) It has been found that the streaming current-potential varies linearly with hydraulic gradient to a slightly higher Reynolds number than the filter velocity. Lack of complete deaeration causes a larger reduction in the filter velocity than the streaming. When "boiling" action takes place anomalous relations between the filter velocity and streaming current occur.
- (h) "Some Relations of Electrokintetic Phenomena to the Hydraulic and Electrosmotic Permeability of Uniform Sands," Howard A. Jongedyk, Ph. D. thesis, June 1968.

(5500)

HYDRODYNAMIC FLUTTER OF SUPERCavitating HYDROFOILS.

- (b) Naval Ship Res. and Dev. Ctr., Dept. of the Navy.
- (d) Experimental, basic research.
- (e) Flat-plate hydrofoils are tested in a free-jet water tunnel at supercavitating conditions to determine the critical velocity as a function of the mass density ratio and other variables. The main purpose is to check the existing theories.
- (g) Critical speeds for the two-degree of freedom flutter of a two-dimensional flat plate were measured. The critical flutter speed was found to be very sensitive to the location of the separation point. It was also revealed that the cavity may be pinched off when the amplitude of flutter is sufficiently large.
- (h) "An Experimental Study of the Hydroelastic Instability of Supercavitating Hydrofoils," C. S. Song and John Almo, St. Anthony Falls Hydraulic Lab. Project Rept. No. 89, Feb. 1967.

(5792)

EFFECT OF GAS NUCLEI ON CAVITATION.

- (b) Naval Ship Res. and Dev. Ctr., Dept. of the Navy.
- (d) Experimental applied research.
- (e) Development and use of new instrumentation for correlating the gas nuclei size distribution to the severity of transient cavitation near inception on a test body in a water tunnel.
- (f) Completed.
- (g) Definite effects are being found relative to gas nuclei and cavitation severity using the new instrumentation and techniques.
- (h) "The Influence of Gas Nuclei Size Distribution on

Transient Cavitation Near Inception," Frank R. Schiebe, St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 107, May 1969. (Not available for distribution).

"Cavitation Occurrence Counting - A New Technique in Inception Research," Frank R. Schiebe, ASME Cavitation Forum, Nov. 30, 1966.

(5795)

NON-NEWTONIAN BOUNDARY LAYER.

- (b) Naval Ship Res. and Dev. Ctr. and Office of Naval Research, Dept. of the Navy.
- (d) Experimental and analytical; Ph.D. thesis study.
- (e) Study of boundary layer structure of laminar, transition and turbulent flows with homogeneous non-Newtonian fluids and Newtonian fluids with injected non-Newtonian additives.
- (f) Completed.
- (g) Calibration tests of impact tubes in dilute polymer flows have indicated an effect of polymer concentration, type of polymer, and tube size. Polyoxy WSR 301 was found to require a larger correction than guar gum. Slot injection of concentrated solutions of Polyoxy and guar gum into the boundary layer of water indicated that Polyoxy tended to diffuse less rapidly than guar gum. Changes in the boundary layer profile due to the injected polymer have also been noted.
- (h) "The Turbulent Boundary Layer in the Flow of Dilute Solutions of Linear Macromolecules," Frank Y. Tsai, Ph.D. thesis, Dec. 1968.

(5796)

IMPACT CAVITATION DAMAGE-II.

- (b) Naval Ship Res. and Dev. Ctr. and Office of Naval Research, Dept. of the Navy.
- (d) Experimental and analytical applied research.
- (e) Utilization of facility previously described under (5495) to clarify fundamental mechanics of failure of solids by erosive impact of liquid drops. Study includes comparison of impact erosion with vibratory cavitation erosion.
- (f) Completed.
- (h) "Comparative Studies of Drop Impingement Erosion and Cavitation Erosion," John F. Ripken, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 105, April 1969. (Not available for distribution.)

(5799)

REVIEW AND ANALYSIS OF PRECIPITATION AND RUNOFF DATA FOR SELECTED WATERSHEDS IN MINNESOTA.

- (b) Office of Water Resources Research, U.S. Dept. of Interior.
- (d) Analytical; basic research.
- (e) Project involved an analysis of precipitation, infiltration and runoff from selected watersheds in Minnesota. The objective of the study was the procurement of information on peak rates of runoff and infiltration rates for selected storms in watersheds. Also of interest was the correlation of basin-wide loss rates with various parameters characteristic of the basins.
- (f) Completed.
- (g) A series of rainstorm floods were analyzed for each of the 5 watersheds selected. An optimization program developed by the Hydrologic Engineering Center of the Corps of Engineers was used to analyze the storm-runoff data and optimize 9 variables associated with the runoff process. As a result of the optimization program, the computed hydrographs agreed very well with the actual hydrographs for each storm. Values of the 9 variables were not constant for each watershed, showing considerable variation. A major part of

this variation can probably be attributed to variations of the intensity and magnitude of precipitation over the watershed; for example, in one storm 6 inches of rainfall occurred over this lower part of a 1200 sq. mi. watershed and only 1 inch over the upper part. The basic rainfall-runoff analysis utilizes a loss-rate analysis employing 5 variables and appears to have considerable merit. Used in combination with average values of these variables it permits a quantitative comparison of the loss rate in various watersheds and thus a comparison of the watersheds.

- (h) "Review and Analysis of Rainfall and Runoff Data for Selected Watersheds in Minnesota," C. E. Bowers and A. F. Pabst, St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 97, June 1968. (Available without Appendices as Bull. No. 8, Water Resources Research Center, Univ. of Minn.)

(6735)

SURFACE PRESSURE FLUCTUATION IN DILUTE SOLUTION OF DRAG REDUCING POLYMERS.

- (b) Office of Naval Research, Dept. of the Navy.
- (d) Experimental.
- (e) Measurements were made of the surface pressure fluctuation under the boundary layer developed on a rotating cylinder as influenced by various concentrations and types of drag reducing polymers.
- (g) Spectrum measurements were made of the pressure fluctuations under the boundary layer of a rotating cylinder with concentration up to 500 ppmw of Polyoxy 301, guar gum and separan. Simultaneous measurements were made of drag. Data correlated well on the basis of measured drag.
- (h) "An Experimental Study of the Effect of Dilute Solutions of Polymer Additive on Boundary Layer Characteristics," J. M. Killen and J. A. Almo, Viscous Drag Reduction, edited by C. S. Wells, Plenum Press, pp. 447-61, 1969.

(6736)

STUDY OF CAVITY SEPARATION OF REAL FLUID.

- (d) Analytical and experimental; Ph.D. thesis.
- (e) The purpose of the project was to determine the location of the boundary layer and cavitation separations near a sharp corner in a viscous fluid.
- (f) Completed.
- (g) Complete Navier-Stokes equations were solved numerically for flows about a cascade of flat plates placed perpendicular to the ambient flow. Singularity at the corner was examined and the location of the separation point was accurately determined. An experiment was also carried out and the result compared with the analytical prediction.
- (h) "Phenomenon of Viscous Separation," Bahram Mozayeny, Ph.D. thesis, March 1970.

(6738)

FRICITION REDUCTION STUDIES FOR BOUNDARY LAYERS ON A ROTATING DISK.

- (b) Office of Naval Research, Dept. of the Navy.
- (d) Experimental basic research; M.S. thesis.
- (e) Evaluation of principal differences in boundary layer developed on a disk rotating in water and in dilute water solutions of selected polymers.
- (f) Completed.
- (h) "The Effect of Long-Chain Polymer Additives on the Flow Around an Enclosed Rotating Disk," C. G. Gilbert, Univ. of Minnesota, M.S. thesis, 1968. "Drag Reduction on a Rotating Disk Using a Polymer Additive," C. G. Gilbert and J. F. Ripken, Viscous

- (6739)
CAVITATION DAMAGE REDUCTION BY FORCED SURFACE OUTGASSING.
(b) Office of Naval Research, Dept. of the Navy.
(d) Experimental applied research.
(e) An attempt to determine if pre-pitting of a metal specimen subjected to vibratory cavitation would lead to reduction of damage by outgassing from the pits. Test and observations confirmed the objectives.
(f) Completed.
(h) "Further Observations on Surface Outgassing as an Influence in Cavitation Damage," J. F. Ripken, 1968 Cavitation Forum, Amer. Soc. Mech Engrs., 1968.
- (6740)
MEASUREMENT OF THE AVERAGE AND FLUCTUATING FORCES AND MOMENTS ON SUPERCAVITATING HYDROFOILS.
(b) Naval Ship Res. and Dev. Ctr., Dept of the Navy.
(d) Experimental basic research.
(e) Measurement of the average and fluctuating values of lift, drag and moment for wedge-like bodies as a function of separation point and other flow parameters.
(f) Completed.
(g) Three different types of severe vibrations were found to occur when the cavity length was equal to or less than one chord. Forced vibration due to the instability of the cavity occurs for all cavity length. Frequency and amplitude are both functions of the cavity length. Vibrations of hydroelastic nature occurred when the cavity length was nearly equal to one chord and 0.4 chord.
(h) "Vibration of Cavitating Hydrofoils," Charles C. S. Song, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 111, Oct. 1969. (Not available for distribution.)
- (6741)
DESIGN OF EROSION RESISTANT CHANNELS.
(b) National Cooperative Highway Research Program, Highway Research Board.
(d) Experimental applied research.
(e) To develop design procedures for armoring drainage channels with riprap to prevent boundary erosion. Studies are being made on the leaching process and critical tractive force for mixtures.
(g) A tentative design procedure has been developed and is being further studied.
(h) "Tentative Design Procedures for Riprap Lined Channels," Alvin G. Anderson, A. S. Paintal, and J. T. Davenport, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 96, June 1968. (Not available for distribution.)
- (6742)
STRATIFIED FLOW STUDIES.
(b) Federal Water Pollution Control Admin., Dept. of the Interior.
(d) Experimental, basic research.
(e) The hydrodynamics of flow of heated water into natural lakes and reservoirs were studied experimentally. Heated water was discharged horizontally from a channel. Temperatures, velocities, and spreading patterns in the vicinity of the outlet were recorded. The experimental tank measured 17 x 40 x 1.6 ft. Velocities were recorded using a tethered sphere method. Some experiments were also carried out in a laboratory flume.
(f) Completed.
(g) Isotherm patterns, surface spreading patterns,
- and velocity distributions near a surface outlet of heated water into a lake have been obtained. Results refer to densimetric outlet Froude numbers and Reynolds numbers from 0.62 to 7.2 and 1,520 to 9,400, respectively. Flow in the experimental tank was of a stratified nature with control from downstream. Heat transfer from the heated water plume to the experimental atmosphere was also of importance. A tentative classification of the various types of flow was given, making a two-layered flow assumption.
(h) "Experimental Study of Warm Water Flow Into Impoundments, Part I: Flow and Heat Exchange Near a Surface Outlet in a Two-Dimensional Flow," H. Stefan and F. Schiebe, Proj. Rept. No. 101. Part II: Temperature and Velocity Instrumentation and Data Processing for the Three-Dimensional Flow Experiments," F. Schiebe, H. Stefan, and N. Hayakawa, Proj. Rept. No. 102. Part III: Temperature and Velocity Fields Near a Surface Outlet in Three-Dimensional Flow," H. Stefan and F. Schiebe, Proj. Rept. No. 103. Univ. of Minn., St. Anthony Falls Hydraulic Lab., Dec. 1968. (Not available for distribution.)
"Heated Water Flow From Channels Into Impoundments," Preprint, ASCE Natl. Water Resources Engrg. Meeting, Memphis, Tenn., Jan. 1970.
- (6743)
DEVELOPMENT STUDY OF AN INSTRUMENT FOR THE MEASUREMENT OF CONCENTRATION OF SUSPENDED SEDIMENT.
(b) Committee on Sedimentation, Water Resources Council.
(d) Experimental.
(e) A feasibility study of an instrument for the measurement of concentration of suspended sediment through its influence on the electrical impedance of the suspending liquid.
(f) Completed.
(g) Preliminary results show measurement can be made up to 6000 parts per million by volume over a temperature range of 40 to 90 degrees F and a salinity of 1-10 gram per 1000 grams of solute.
(h) "A Feasibility Study for the Measurement of Suspended Sediment Concentration," J. M. Killen, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. 109, 1969. (Not available.)
- (6744)
FREE STREAMLINE FLOW OVER DISCONTINUITIES IN A BOUNDARY LAYER.
(b) National Science Foundation.
(d) Theoretical and experimental; doctoral thesis.
(e) The purpose of the research is to understand the mechanism of cavity formation at an obstruction in a boundary layer subjected to low pressures. Calculations have been made to describe the boundary cavity formed by various kinds of discontinuities that are often found in hydraulic structures. Experiments are being made to measure the cavity properties.
- (6745)
GATED CONTROL STRUCTURE - MODEL STUDY.
(b) Harza Engineering Co., Chicago; Metropolitan Water District of Southern Calif., Los Angeles.
(d) Experimental design and operation.
(e) Model studies of the flow through gate structures, calibration of gates systems to establish head difference - gate opening curves, and air entrainment release and gate vibrations.
(h) "Model Studies - Foothill Feeder Project, Part I: Regular Gate Structure," Alvin G. Anderson, David J. Anderson and Roy M. Kuha, St. Anthony Falls Hydraulic Lab. Proj. Rept. No. 91, Feb. 1967.

(Not available for distribution.)

(6746)

DISPERSION OF CHLORINE SOLUTION IN TURBULENT PIPE FLOW.

(b) Harza Engineering Co., Chicago; Metropolitan Water District of Southern California, Los Angeles.

(d) Experimental.

(e) Chlorine concentration profiles are being measured downstream from the point of injection of a concentrated chlorine solution. Injection is normal to the flow at various distances from the pipe wall. A series of tests are being conducted using one, two and multiple injectors to study the relationship between number of injectors used and the "mixing length" required to reach a given degree of concentration uniformly across the pipe.

(f) Completed.

(h) "Model Studies of Chlorine Solution Dispersion in Turbulent Pipe Flow," J. W. Hayden, St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 95, 1968. (Not available for distribution.)

(6747)

MODEL STUDY OF DROP SHAFT FOR DEEP TUNNEL DRAINAGE.

(b) Harza Engineering Co., Chicago; City of Chicago, Illinois.

(d) Experimental design.

(e) Experimental design studies of the operation of various drop shaft designs with variations in discharge and tailwater levels. Entrainment of air and impact forces are being measured.

(f) Completed.

(h) "Model Studies--Lawrence Avenue Sewer System," Alvin G. Anderson and W. Q. Dahlin, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 100, Oct. 1968. (Not available for distribution.)

(6749)

PREPARATION OF COMPUTER PROGRAM SIMULATING MAIN INTERCEPTOR SYSTEM FOR MINNEAPOLIS - ST. PAUL SANITARY DISTRICT.

(b) Minneapolis - St. Paul Sanitary District.

(d) Analytical.

(e) The objective of this study is the preparation of a mathematical model for real-time computation of runoff and storm flow in the interceptor sewers of the Minneapolis - St. Paul Sanitary District. The model as developed consists of three parts: (1) hydrologic analysis of runoff from the 45 sq. mi. urban area, (2) diversion analysis to determine the quantities entering the interceptor sewers, and (3) routing of the flow through the sewer to the waste treatment plant.

(f) Completed.

(g) "The Real-Time Computation of Runoff and Storm Flow in the Minneapolis - St. Paul Interceptor Sewers," C. E. Bowers, G. S. Harris, and A. F. Pabst, St. Anthony Falls Hydraulic Lab., Memo. No. M-118, Dec. 1968.
"Development of a Computer Program to Route Runoff in the Minneapolis - St. Paul Interceptor Sewers," G. S. Harris, Univ. of Minn., St. Anthony Falls Hydraulic Lab., External Memo. No. 121, Dec. 1968.
"Real-Time Estimation of Runoff in the Minneapolis - St. Paul Metropolitan Area," G. S. Harris, Univ. of Minn., St. Anthony Falls Hydraulic Lab., External Memo. No. 119, Dec. 1968.
"Mathematical Models of Major Diversion Structures in the Minneapolis - St. Paul Interceptor Sewer System," G. S. Harris, Univ. of Minn., St. Anthony Falls Hydraulic Lab., External Memo. No. 120, Dec. 1968.

(6750)

CHARACTERISTICS OF THE AIR ENTRAINMENT DUE TO THE IMPACT OF A FLUID FREE JET INTO A POOL OF SIMILAR FLUID.

(b) Laboratory thesis study.

(d) Experimental applied research; M.S. thesis.

(e) The study involves the use of photographic and electronic means to determine the shape and consistency (percent air) of the air entrainment region. Certain dimensionless parameters will be varied in an attempt to relate the air entrained in a hydraulic model to the air which will be entrained in the prototype installation. Velocity profiles, particularly at high jet Reynold's number, will be examined.

(f) Completed.

(h) "Air Entrainment and Velocity Profile Characteristics Upon Impact of a Free Fluid Jet Into a Similar Fluid," David J. Anderson, Master's thesis, June 1968.

(6751)

MODEL STUDY OF SUBMERGED OPEN CHANNEL CONSTRICTIONS.

(b) A laboratory thesis study.

(d) Experimental research; M.S. thesis.

(e) This study will try to analyze the relationship between the upstream depth and the constriction depth for an open channel constriction, depending on the degree to which the constriction has been overtopped by the flow. A sediment bed and a recirculating flume will be used.

(f) Completed.

(h) "The Effect of Submerged Long Constrictions on the Dynamic Equilibrium Depth of Scour in Open Channels," John T. Davenport, Master's thesis, July 1968.

(6761)

WAVES IN STRATIFIED FLUID.

(b) Office of Naval Research, Dept. of the Navy.

(d) Experimental.

(e) An experimental facility is being developed wherein progressive waves of specified characteristics in stratified fluid could be produced.

(6762)

AN EVALUATION OF THE ACOUSTIC GAS NUCLEI SIZE DISTRIBUTION INSTRUMENT.

(b) Naval Ship Res. and Dev. Ctr., Dept. of the Navy.

(d) Experimental.

(e) The objective of the program is to perform a complete evaluation of the acoustic attenuation method for determining the gas nuclei size distribution in water.

(6763)

SCALING LAWS ASSOCIATED WITH PRESSURE FLUCTUATION IN THE VICINITY OF A HYDRAULIC JUMP.

(b) National Science Foundation.

(d) Analytical; basic and applied research.

(e) The primary objectives of such a study are (1) experimental determination of a stochastic model of the turbulent characteristics of the hydraulic jump and the influence of the various flow parameters (i.e., Froude, Reynolds, Weber, etc., numbers) on the model and (2) evaluation of the scaling laws associated with extrapolation of the turbulent characteristics of laboratory scale models to prototype proportions.

(g) Experimental studies have been performed in one channel 20' wide and 36" deep and in a larger channel 9 ft. wide and 6 ft. deep. Preparations are underway to obtain data in a prototype stilling basin on the Mississippi River.

- (7664)
A STUDY OF A MULTIPLE-JET CONTROL AND DISSIPATION SYSTEM FOR HIGH HEAD HYDRAULIC STRUCTURES.
(b) National Science Foundation.
(d) An experimental laboratory study.
(e) The study seeks to establish design guidelines for a safer and less expensive new device for the control and dissipation of energy contained in water released from high head hydraulic structures.
- (7665)
LABORATORY DATA ACQUISITION SYSTEM.
(b) National Science Foundation.
(d) Field investigation; equipment grant development.
(e) A laboratory wide digital data collection system is being designed.
- (7666)
CONTROLLED TEMPERATURE REGIMES IN OUTDOOR EXPERIMENTAL PONDS.
(b) National Water Quality Laboratory, Federal Water Pollution Control Administration, Dept. of the Interior.
(d) Applied research and design.
(e) Means and methods to artificially heat, cool, and mix outdoor experimental ponds with 1/4-acre surface area are investigated. Ponds will serve to study aquatic life under the effect of variable temperatures. The study is broken down into collection and analysis of climatological data, heat loss computations, and design of heat exchange facilities.
- (7667)
EVALUATION OF SELECTED COMPUTER PROGRAMS IN HYDROLOGY.
(b) Office of Water Resources Research.
(d) Analytical; applied research.
(e) The objective of this study is an evaluation of selected computer programs in the field of hydrology to assist in the application of these programs by the designer or practicing engineer. Research efforts have resulted in the development of many computer programs that should be very helpful to the designer of hydraulic structures and to others concerned with the analysis of hydrologic problems. In an effort to assist the potential user, selected programs and possibly mathematical models will be studied and compared with established procedures. This should provide information on the scope and procedures for use of the programs, as well as comparative results, in terms of methods with which the potential user is familiar.
(f) Numerous programs have been received from government agencies and other sources and are in the process of being evaluated.
(h) A preliminary report is in preparation.
- (7668)
FRICTION FACTORS FOR HELICAL CORRUGATED ALUMINUM PIPE.
(b) The Aluminum Association, New York.
(d) Experimental; applied research.
(e) Manufacturers of aluminum helically corrugated pipe were desirous of determining friction factors for such pipes by actual measurement. Pipes of 12, 18 and 24 inch diameters were provided. Measurements were made of discharge versus slope of hydraulic grade line for a range of Reynolds numbers in each size. A velocity profile across one diameter was measured at a high Reynolds number for each size of pipe near its downstream end.
(f) Completed.
(g) It was demonstrated that as the helix angle be-
- comes smaller than 90° (standard corrugated pipe has a 90° angle) the friction factor decreases. The friction factor also decreases as pipe size decreases. The former effect is probably due to turbulence reduction associated with the rotating component of the flow and the latter with decrease in relative roughness.
(h) "Friction Factors for Helical Corrugated Aluminum Pipe," E. Silberman and W. Q. Dahlin, St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 112. (Available from St. Anthony Falls Hydr. Lab. for \$2.00.)
- (7669)
CALIBRATION STUDIES OF TWO 36-INCH HAMMEL-DAHL FLOW TUBES.
(b) Hammel-Dahl Division, International Telephone and Telegraph Corp.
(d) Experimental laboratory evaluation.
(e) The discharge characteristics for Reynolds numbers ranging from 0.5 to 4.5×10^5 were determined for two large flow meters intended for a nuclear power generating plant.
(f) Completed.
(h) "Calibration Studies of Two 36-inch Hammel-Dahl Flow Tubes," J. F. Ripken and B. D. Ward, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Memo. M-116, Jan. 1969. (Not available.)
- (7670)
A MODEL STUDY OF A DIKE ENCLOSURE AT THE EASTERN END OF LAKE ERIE.
(b) Bethlehem Steel Corporation.
(d) Experimental; applied research.
(e) The Bethlehem Steel Corporation was considering requesting a permit to build a dike in Lake Erie adjacent to its Lackawanna, New York, plant enclosing about one sq. mi. for containing the slag produced at the plant. It was necessary to know how the proposed dike would effect operation in the southern entrance to the Buffalo, New York harbor (wave heights, ice drift, etc.) and how it would effect currents carrying littoral drift and polluted creek flows past existing water intakes and a beach. The shape of the dike was to be developed as part of the study.
(f) Completed.
(g) For the shape of dike recommended, it was found that there would be no noticeable adverse affects of the dike on waves and currents.
(h) "A Model Study of A Dike Enclosure at the Eastern End of Lake Erie," E. Silberman, W. Q. Dahlin, and A. S. Paintal, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Prof. Rept. No. 104, April 1969. (Not available for distribution.)
- (7671)
MODEL STUDY OF INTAKE AND DISCHARGE STRUCTURES FOR ZION NUCLEAR STATION.
(b) Harza Engineering Company.
(d) Experimental; applied research.
(e) The model was limited to study of the previously designed structures for flow of homogeneous fluid only. The intake structure has provision for reverse flow of warm water in part of the system to prevent ice blockage in winter. There were other unusual design features contributing toward minimum construction cost and minimum disturbance of the existing lake bottom. The objective was to check and modify the design for minimum head loss and good flow distribution in both structures.
(f) Completed.
(g) Certain modifications were made in the original design to accomplish the objectives.
(h) "Model Study of the Intake and Discharge Struc-

tures for Zion Nuclear Station," E. Silberman and J. W. Hayden, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 110, Sept. 1969. (Not available for distribution.)

(7672)

MODEL STUDY - SPILLWAY FOR REZA SHAH KABIR PROJECT.

- (b) Harza Engineering Company.
- (c) Experimental design.
- (e) Experimental design of chute spillway and the effect of the jet on river regime and erosion pattern.
- (f) Completed.
- (g) In order to project jet into river channel the bucket was designed to deflect the jet downstream to minimize erosion and secondary currents.
- (h) "Model Study - Spillway of the Reza Shah Kabir Project, Government of Iran," Alvin G. Anderson and K. E. Foerster, Univ. of Minn., St. Anthony Falls Hydraulic Lab., Proj. Rept. No. 106, May 1969. (Not available for distribution.)

(7673)

STATE-OF-THE-ART MODELING HEAT SPREAD INTO LAKES.

- (b) Argonne National Laboratory, U.S. Atomic Energy Commission.
- (d) This project is a state-of-the-art survey of physical (hydraulic) modeling of heat dispersion from condenser cooling discharges to lakes.

(7674)

EFFECT OF POLYMER ON VELOCITY PROFILES IN A COMMERCIALLY ROUGH PIPE.

- (d) Experimental; Master's thesis.
- (e) Velocity profiles were measured with a flattened pitot tube across a diameter of a 4-inch wrought iron pipe using pure water and water with polyox added. The flow carried from smooth to transitionally rough as the Reynolds number increased. The purpose of the project was to correlate the decrement in velocity usually occurring in rough pipe profiles with the concentration of polymer added and to compare the results with available theory.
- (f) Completed.
- (g) The experimental results confirmed that polymer reduces drag in the turbulent regime with rough surfaces as it does for smooth surfaces. Velocity profiles are displaced downward by roughness for small concentrations but for larger concentrations (~20 ppm) they are displaced upward, even above the smooth surface profiles without polymer. There may be an optimum concentration for each Reynolds number (or roughness). It was not possible to correlate results well with theories based on critical shear velocity for the polymer used.
- (h) "Effect of Polymer on Velocity Profiles in a Commercially Rough Pipe," Chander K. Sehgal, Master's thesis, Jan. 1970.

(7675)

THE PROBABILISTIC CHARACTERISTICS OF BED LOAD TRANSPORT IN ALLUVIAL CHANNELS.

- (d) Theoretical and experimental; Ph.D. thesis.
- (e) An investigation into the probability of movement of sediment by flowing water. Experiments at very low rates of transport were carried out to test theoretical results.
- (f) Completed.
- (h) "The Probabilistic Characteristics of Bed Load Transport in Alluvial Channels," Amreek S. Paintal, Ph.D. thesis, June 1969.

(7676)

LAMINAR BOUNDARY LAYER BETWEEN TWO PARALLEL STREAMS.

- (d) Analytical; Master's thesis.
- (e) The interface between two parallel streams has been assumed flat in most of the existing theories. The purpose of this research is to calculate the deflection of the interface and, thus, determine the error involved in the previous calculations.
- (f) Completed.
- (g) Boundary layer velocity profiles and the deflection of the interface between two parallel streams were computed by solving the boundary layer equations.
- (h) "Laminar Boundary Layer Between Two Parallel Streams," Pierre Mignot, Master's thesis, Dec. 1969.

(7677)

SCOUR AND PROTECTION AGAINST SCOUR AT STRUCTURES.

- (b) Mississippi State Office, Soil Conservation Service, U.S. Dept. of Agric., and Agricultural Research Service, U.S. Dept. of Agric., in cooperation with the Minnesota Agric. Exptm. Sta. and the St. Anthony Falls Hydraulic Lab.
- (d) Experimental; generalized applied research for development and design.
- (e) (1) To determine the need for protective riprap, the area requiring protection, and the size of riprap required at the inlet and outlet of a box inlet drop spillway proposed for Tillatoba Creek, Yazoo River Watershed, Tallahatchie County, Mississippi; and (2) laboratory studies to determine for the box inlet drop spillway, the straight drop spillway, and the SAF stilling basin the size and shape of the scour in sand beds and the size and placement of riprap to protect against scour.

INTER-AGENCY SEDIMENTATION PROJECT IN COOPERATION WITH ST. ANTHONY FALLS HYDRAULIC LABORATORY:

(194)

A STUDY OF METHODS USED IN MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS.

- (b) Committee on Sedimentation, Water Resources Council; personnel of the U.S. Army Corps of Engrs. and the U.S. Geological Survey are actively engaged on the project.
- (d) Experimental; applied research and development.
- (e) Drawings and specifications are available to facilitate the manufacture of suspended-sediment and bed-material samplers, particle-size analyzers, and associated laboratory equipment. Approved designs for the measurement of suspended sediment include a single stage sampler, 4-, 22-, and 62-pound depth-integrating samplers, electrically operated point-integrating suspended samplers weighing 100-, 200-, and 300-pounds, and an intermittent pumping type sampler. Samplers for the measurement of bed material include a piston-type hand-operated sampler, 30-pound hand-line sampler, and 100-pound sampler for cable suspension. Additional items are a sediment sampler-splitter, a bottom-withdrawal sedimentation tube for size analysis, and visual-accumulation sedimentation tubes with recording equipment for particle size analyses of sands. The primary objective of the current program is the development of an instrument to automatically record suspended-sediment concentrations in flowing streams.
- (g) Testing has continued on the intermittent pumping-type samplers, turbidimeters, filtering devices, electrical and nuclear sensing devices. Results of field tests on bottling-type pumping samplers

are favorable. Laboratory tests have been completed on a compact portable pumping sampler with a 48-pint-size sample bottle capacity.

A control that automatically adjusts the frequency of pumping sampler operation to match stream discharge has been built and is currently being tested.

A Fischer-Porter water level recorder was modified to include an event marker device that would record on the paper tape the time each pumped sample was taken. Sampler can also be cycled by a signal from the Fischer-Porter recording unit. Laboratory tests on an electrical impedance device indicates that the method is a reasonably reliable means for rapidly determining the concentration of suspended-sediments in a stream. Peripheral water conditioning equipment and electrical controls for a field installation are being designed. Field tests on the radiological sedimentation gauges have produced favorable relationships, however, maintenance costs have been excessive in both time and money.

- (h) "Laboratory Investigation of Pumping-Sampler Intakes," Report T, Progress Rept. 59-pp, April 1966, price 75 cents per copy.
Catalog - "Instruments and Reports for Fluvial Sediment Investigations, Federal Inter-Agency Sedimentation Project," 67 pages, Revision Oct. 1966, price \$1.00 per copy. For sale by the District Engr., St. Paul District, Corps of Engrs., 1217 U.S. Post Office and Custom House, St. Paul, Minnesota 55101.

SCIENCE ENGINEERING ASSOCIATES, Division of Kaman Sciences Corporation, 2450 Mission Street, San Marino, California 91108. Dr. Lars Skjelbreia, Vice President and General Manager.

(7626)

FEASIBILITY STUDY FOR A SURGE-ACTION MODEL OF MONTE-REY HARBOR, CALIFORNIA.

- (b) Corps of Engineers, Vicksburg, Mississippi.
- (d) A theoretical study based on applied research.
- (e) This study involved the analyzing of oscillating characteristics and critical frequencies of long period waves for Monterey Bay as a whole, Monterey, Moss Landing and Santa Cruz Harbors.
- (f) Completed.
- (g) The report attempts to answer basic questions regarding the feasibility of reproducing in an engineering model the surge phenomenon that at various times occurs in the Monterey Harbor, California. Sea and swell data are summarized for the deep-water vicinity area and for Monterey Bay itself. Statistical data for the occurrence of long-period waves at three sensor positions are examined and compared with similar type data for Santa Cruz Harbor and for Half Moon Bay Harbor. A detailed study is made of the manner of propagation of long period waves into Monterey Bay. In the final sections of the report it is concluded that the conditions in the Bay can be modelled with reasonable chance of success, and suggestions are made for the calibration of the model and for the analysis and interpretation of the results it may yield.
- (h) "Feasibility Study for a Surge-Action Model of Monterey Harbor, California," B. W. Wilson, J. A. Hendrickson and R. E. Kilmer, Contract Rept. No. 2-136, 180 pages, published by U.S. Army Engr. Waterways Expt. Sta., Corps of Engrs., Vicksburg, Miss., Oct. 1965.

(7627)

WAVE AND SURGE-ACTION STUDY FOR LOS ANGELES-LONG BEACH HARBORS.

- (b) U.S. Army Corps of Engineers, Los Angeles District.
 - (d) A theoretical study as well as planning for field instrumentation.
 - (e) Los Angeles-Long Beach Harbors have long been afflicted by surge troubles. Now the tremendous expansion of commerce in the ports necessitates consideration of new construction for future basins which will completely change the shapes of the residual outer harbor areas within the lee of the breakwaters. Awareness of the problems inherent in such new development led to a study of all necessary information on the best schemes for development of the harbors. These plans would have to meet the expansion requirements of the ports and overcome as far as possible the surge-action troubles for which the area has long been known. Therefore the purposes of this study were to determine optimum design of harbor extensions, adequacy of existing breakwater, identification of excitations affecting harbor and protection of existing facilities.
 - (f) Completed.
 - (g) During the course of this study the following was accomplished: (1) for the existing and planned harbor extension the oscillating characteristics and critical frequency of long period waves were determined theoretically for San Pedro Bay as a whole, Los Angeles and Long Beach Harbors and their surrounding basins, ships and channels; (2) from field data the critical period of long waves in various parts of the two harbors was determined and compared with theoretical results; (3) recommendation for the design of a hydraulic model simulating observed and deduced characteristics of the harbors; (4) planning a program of data collection, including design of the necessary instrumentation and data analysis; and (5) analyzing the response of moored ships to long period waves.
 - (h) "Wave and Surge-Action Study for Los Angeles-Long Beach Harbors," Basil W. Wilson, Yuan Jen, James A. Hendrickson, Hennek Soot and Charles A. Burns, Vols. I and II, Final Report under Contract DACW 09-67-C-0065, Vol. I, 387 pages, Vol. II, 66 pages, published by U.S. Army Corps of Engrs., Los Angeles District.
- (7628)
- THE TSUNAMI OF THE ALASKAN EARTHQUAKE, 1964: ENGINEERING EVALUATION.
- (b) Coastal Engineering Research Center.
 - (d) A theoretical study, including field investigations
 - (e) The purpose of this study is to evaluate the tsunamis of Good Friday, 1964. The evaluation is directed to an engineering view of the causes, effects, and future protective measures. A secondary purpose is to evaluate the oceanographic and geophysical nature of tsunami generation.
 - (f) Completed.
 - (g) Nature of the earth dislocation is described and related to generation, propagation, and dispersion of the main tsunami waves. Propagation of this enormous wave is followed to Canada, Washington, Oregon and California, to Hawaii, Russia, Japan and New Zealand. Detailed studies of the main tsunami and local seismic sea waves are given for damaged areas in Alaska, especially those in Prince William Sound. In addition to the wave analysis for each place, an engineering evaluation is presented for severely damaged areas.
 - (h) "The Tsunami of the Alaskan Earthquake, 1964: Engineering Evaluation," Basil W. Wilson and Alf

(7629)

OSCILLATING CHARACTERISTICS OF LAKE ERIE.

- (b) U.S. Army Engineer District, Lake Survey, Detroit, Michigan.
- (d) Theoretical analysis.
- (e) The purpose of the study is to apply a generalized computer program to determine the natural modes and period of oscillation of Lake Erie.
- (f) Completed.
- (g) SEA has developed a numerical technique for computing the period and mode shape of free oscillations in closed basins and harbors. The problem is treated in two-dimensions (three-dimensional with time included). Essentially the problem is resolved into an equivalent eigenvalue matrix problem, the solution of which yields the natural periods of lake oscillation and the corresponding normal modes of surface variations. The theoretical analyses showed that the first period of oscillation is in almost exact agreement with the observed value. The calculated periods for the second, third and fourth modes, however, are less than the observed values. Based on the study, several instrument sites have been recommended by SEA to improve the data collection program.
- (h) "Oscillating Characteristics of Lake Erie," J. A. Hendrickson, Final Report prepared for U.S. Army Engineer District, Lake Survey, Detroit, Michigan under Contract No. 35-68-C-0028, June 1968.

(7630)

DYNAMIC DESIGN OF OFFSHORE MOORING SYSTEMS.

- (d) Theoretical analysis, applied research.
- (e) A computer program has been developed for calculating the full dynamic stresses in a typical mooring cable holding an object such as a ship or buoy in a design storm involving appropriately compatible wind, wave and current conditions. The procedure takes into account the motions of the object under the sea state, the elastic stretch of the cable, the lifting and deposition of any ground lines that may be employed at the anchor, and if required, the drag and inertial forces imposed on the cable by its motion with the wave field. Because of the great complexity of the problem of determining the dynamic tension in the cable, the simplification is made that the waves bearing on the moored object are regular long-crested waves whose height and period can be specified. It is further assumed that the cables lie only in a vertical plane.
- (f) Completed.
- (g) The program has successfully been applied to the analysis of several buoy systems used for unloading super tankers. The system consisted of a 40 ft. diameter buoy with four equally spaced mooring lines, each line having up to three clumps. The survival of the buoy system was tested by subjecting the system to near breaking waves.

(7631)

WAVE FORCE CALCULATION FOR THREE-DIMENSIONAL STRUCTURES COMPOSED OF TUBULAR MEMBERS.

- (d) A theoretical study including correlation with experimental data.
- (e) The purpose of this project was to develop a method to determine the distribution or total forces on the various members of a complex structure composed of horizontal, vertical and inclined

cylinders when subjected to wave action. By proper use of vector and matrix algebra, together with high speed digital computing, these forces can be determined for an entire structure.

- (f) Completed.
- (g) In general the program will provide information for each specified phase angle: (1) Distribution of normal and axial forces along the length of each member in terms of three components. (2) Resultant of normal and axial forces at each point along the cylinder. (3) Integrated normal and axial forces along the cylinder in terms of three mutually perpendicular components. Resultant of the three components and center of action is also given. (4) Summation of forces on all members of the structure in terms of three mutually perpendicular components. Total resultant force and center of action is also given. (5) Summation of moments about the three principal axes.
- (h) "Wave Force Calculation for Three-Dimensional Structures Composed of Tubular Members," Lars Skjelbreia and J. A. Hendrickson, published in Proceedings of OECON 1966.

(7632)

STRESS ANALYSIS OF THREE-DIMENSIONAL STRUCTURES COMPOSED OF TUBULAR MEMBERS.

- (d) Theoretical study in applied research.
- (e) A computer program has been developed capable of stress analyzing any three-dimensional structure composed of tubular members subjected to the loading of wind, waves and current.
- (f) Completed.
- (g) The input data for the computer program consists of the physical characteristics of the structure, coordinate locations of the member joints, the height and period of the selected design wave, and the water depth. The program automatically uses a high order gravity wave theory on the design wave and uses Morison interaction theory for calculating the force distributions on the individual members. In the computer program, the distribution is replaced by twenty-one discrete load points. The program has been prepared assuming that all members are cylindrical tube-like beams. Currently the program is capable of analyzing any structure containing members and nodes not exceeding two hundred fifty and one hundred twenty-five, respectively. The program will automatically select the appropriate theory for the design wave parameters and location water depth, treat the design wave accordingly, and then complete the stress analysis. Future plans call for including dynamic stresses due to the inertia of the members, buckling criteria for each member, modification of the influence coefficients due to compressive axial loading, natural frequency of the structure, and the soil interaction problem.

SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, SAN DIEGO, La Jolla, California 92037.
Dr. Charles S. Cox.

(4500)

A STUDY OF INTERNAL WAVES IN THE OCEAN.

- (b) Office of Naval Research.
- (e) Methods of detection of model structure of internal waves are being studied.
- (g) Vertical motions of isotherms can be accurately measured with short vertical arrays of thermistors. Signals from single probes are inadequate because of thermal microstructure.

(6289)
STUDY OF STRUCTURE OF TEMPERATURE AND SALINITY IN THE SEA.

- (b) Office of Naval Research.
- (c) Measurements of the spatial distribution of temperature and salinity gradients are made from a freely falling probe. They are related to heat and salt flows, turbulent mixing, and the entropy budget of the ocean.
- (g) The vertical component of heat flux in California near shore waters is as low as 3×10^{-4} cal/cm² sec at 300m depth despite clear evidence of active turbulent mixing.
- (h) "Fine Structure in the Oceanic Thermocline," T. R. Osborn, Ph.D. thesis, Univ. of Calif., San Diego, 1969.

SCRIPPS INSTITUTION OF OCEANOGRAPHY, See also, UNIVERSITY OF CALIFORNIA, SAN DIEGO.

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY, Department of Civil Engineering, Rapid City, South Dakota 57701. Professor Donald A. Thorson.

(041W)
INVESTIGATION OF THE WATER RETENTION CHARACTERISTICS OF SOILS USED FOR CONSTRUCTION OF WASTEWATER STABILIZATION PONDS.

- For summary see Water Resources Research Catalog, 8,0292, Vol. 2.
- (c) Asst. Prof. Floyd L. Matthew.
- (f) Completed.
- (h) J. Water Poll. Control Fed., Nov. 1969.

(7633)
DESIGN CRITERIA FOR CONTROLLED SCOUR AND ENERGY DISPERSION AT CULVERT OUTLETS USING ROCK AND A SILL.

- (b) South Dakota Dept. of Highways.
- (c) Prof. Donald A. Thorson.
- (d) Experimental; applied; M.S.
- (e) Provides design tables for selection of size of rock, quarried or field, geometry of rock basin at outlet of circular culverts with flared-ends. Sills also studied.
- (f) Completed.
- (g) Round rock as effective as angular rock when sized according to square screen-openings. Sills economical for scour control and energy dissipation.

(7634)
AN HISTORICAL ACCOUNT OF AMERICAN CONTRIBUTIONS TO ESTIMATING RAINFALL EROSION.

- (b) Voluntary project.
- (c) Prof. Emeritus Shu-t'ien Li, P. O. Box 1810, Rapid City, South Dakota 57701.
- (d) For paper to International Water Erosion Symposium, Prague, Czechoslovakia, June 15-21, 1970.

SOUTH DAKOTA STATE UNIVERSITY, Civil Engineering Department, Brookings, South Dakota 57006. Professor E. E. Johnson, Department Head.

(7635)
FINE SEDIMENT SEPARATOR.

- (c) Fred F. M. Chang, Assoc. Prof.
- (d) Experimental laboratory research.
- (e) To construct an instrument to separate finer sediment particles. The instrument is a 1-ft.

deep, 3-in. wide, 4-ft. long plastic box laid on a horizontal floor. Water is slowly circulated, having uniform velocity across the section. A 3-in. vertical pipe is attached to the upstream of the box to supply testing samples in to the instrument. The pipe is 8-in. high and filled with water. And thus, sediment particles fed into the pipe will fall in the water and reach this terminal velocity before going into the box. In the box, sediment particles are exposed into a uniform horizontal velocity and carried to downstream. The horizontal distances of travel are inversely proportional to their terminal velocities, so to particle sizes, and the particles are, therefore, separated according to their sizes.

(7636)

EROSION PROTECTION FOR THE OUTLET OF SMALL AND MEDIUM CULVERTS.

- (b) South Dakota Dept. of Highways in cooperation with the U.S. Dept. of Transportation.
- (c) Fred F. M. Chang, Assoc. Prof.
- (d) Experimental laboratory research.
- (e) This study is conducted as a pilot study to investigate and evaluate the feasibility of an erosion control work for the outlet of small and medium culverts. The proposed control work consists of a recessed stilling basin armored with gravel and a transverse impact wall. The test indicated that this control work was quite effective and perhaps most economical compared with other conventional control works. Often, a recessed stilling basin is not used because it is hazardous to the traffic safety but, considering the advantage in simplicity, inexpensiveness, and effectiveness, it is recommended particularly in the arid areas.
- (f) Completed.

(7637)

REDUCTION OF SCOUR AROUND BRIDGE PIERS.

- (b) South Dakota Dept. of Highways in cooperation with the U. S. Dept. of Transportation.
- (c) Fred F. M. Chang, Assoc. Prof.
- (d) Experimental laboratory and field study. Applied research.
- (e) To determine experimentally the effect of circular piles placed immediately upstream a pier on the reduction of scour depth around the pier. A field study is now in progress to determine the validity of this method which had been found quite effective in the laboratory model test.

(7638)

SCOUR AND FILL IN THE MISSOURI RIVER AS RELATED TO THE WATER RESOURCES PLANNING.

- (b) Office of Water Resources Research.
- (c) Fred F. M. Chang, Assoc. Prof.
- (d) Applied research.
- (e) Use continuity equation of sediment to predict the river bed variations between Oahe Dam and Big Bend Dam in South Dakota. Results will be checked with field data and the relation between river bed variations and water resources planning will be examined.

UNIVERSITY OF SOUTHERN CALIFORNIA, Foundation for Cross-Connection Control Research, School of Engineering, University Park, Los Angeles, California 90007. Dr. E. Kent Springer, Foundation Director.

- (49) FOUNDATION FOR CROSS-CONNECTION CONTROL RESEARCH.
 (b) Southern California Water Utilities Association, Inc.
 (d) Experimental laboratory and field investigations; basic and applied research; sponsored and thesis (M.S., Engr., and Ph.D.).
 (e) Sponsored-- evaluation of various back-flow prevention devices under both laboratory and field conditions. Laboratory-- a new hydraulic research laboratory has been established with capabilities of up to 4500 gpm at 300 ft. head. The new facility includes parallel circuits and flow meter calibration capabilities for all sizes up through 16 inches.
 (g) Standardized laboratory and field evaluation procedures as well as minimum design and operating specifications have been established for back-flow prevention due to cross-connections.
 (h) "Manual of Cross-Connection Control," - 4th Edition.
 "Specifications for Back-Flow Prevention Devices," 69-2.
 "Cross Talk," - a quarterly publication of development news pertaining to cross-connection control.

UNIVERSITY OF SOUTHERN CALIFORNIA, Department of Mechanical Engineering, University Park, Los Angeles, California 90007. Professor Raymond C. Binder.

- (7639) SHOCK ANALYSIS OF FLUID SYSTEMS USING ACOUSTIC IMPEDANCE AND THE FOURIER TRANSFORM; APPLICATION TO WATERHAMMER PHENOMENA.
 (c) Prof. Raymond C. Binder and Arthur A. Winquist.
 (d) Analytical study of waterhammer; Engineer in Mechanical Engineering thesis.
 (e) Using acoustic impedance and the Fourier transform in a digital computer program, waterhammer excess pressure head resulting from valve closure at the end of a straight pipe was calculated for several cases. The results of this theoretical analysis compared very favorably with experimental data and results using traditional waterhammer solution techniques.
 (f) Completed.
 (g) Calculated excess pressure head was closely comparable to the excess pressure experienced in actual experimental tests and the excess pressure head using traditional solution techniques. The Fourier technique satisfies an existing requirement for an alternate approach to the present laborious methods used in calculating waterhammer pressures.
 (h) Thesis, and "The Shock and Vibration Bulletin" - Bull. 40-Part 2, Dec. 1969 - available through The Shock and Vibration Information Center, Naval Research Laboratory, Washington, D.C.

- (7640) HIGH VELOCITY AIR DISTRIBUTION SYSTEMS.
 (c) Prof. E. Kent Springer and Donald C. Glover.
 (d) Analytical study of ducting for a multiple-duct, high-velocity air conditioning system; M.S. in Mechanical Engineering thesis.
 (e) A digital computer program was developed and tested by laboratory evaluation which will size the ducts and predict velocity and head loss in a system.
 (f) Completed.
 (g) A valid digital computer program for duct sizing and blower requirements of a multiple take-off,

- high velocity air conditioning system was developed.
 (h) Thesis.

SOUTHERN ILLINOIS UNIVERSITY, School of Technology, Fluid Mechanics Laboratory, Carbondale, Illinois 62901. Dr. Thomas Jefferson, Dean of School.

- (7641) STUDIES OF THE FLOW, BONDING AND DAMPING CHARACTERISTICS OF A SQUEEZE FILM UNDER DYNAMIC CONDITIONS.
 (b) National Aeronautics and Space Administration.
 (c) Dr. Philip K. Davis, in charge of Fluid Mechanics.
 (d) Experimental and theoretical; basic research.
 (e) The research consists of a series of experimental and theoretical investigations to determine the flow, bonding, and damping characteristics of a liquid squeeze film under dynamic conditions.
 (g) The effect of viscosity, film thickness and load pulse duration on the bonding strength has been determined. The effect of kinematic viscosity, film thickness, and frequency on the damping properties are being studied.
 (h) "Bonding and Flow Properties of Liquid Squeeze Films," Thesis by Douglas Colclasure, Southern Illinois Univ. Library.
 "A Study of the Damping Characteristics of the Liquid Squeeze Film," Thesis by Takeya Yabe, Southern Illinois Univ. Library.
 "The Dynamic Liquid Squeeze Film," Thesis by Robert C. Riepe, Southern Illinois Univ. Library.

- (7642) TURBULENT MIXING IN ZONES OF SEPARATION (REF. 13-06-15).
 (c) Dr. Sedat Sami, Assoc. Prof.
 (d) Experimental project for master's thesis.
 (e) The characteristics of the turbulent velocity and pressure fields and the effectiveness of the turbulent mixing zone in several separated flow cases are the main objectives of this project. It will eventually help better understand the mechanism of turbulent separated flows.

- (7643) STUDIES OF THE MOTION OF SOLID SYMMETRIC BODIES IN A ROTATING VISCOUS FLUID.
 (b) National Science Foundation.
 (c) Philip K. Davis, Assoc. Prof.
 (d) Experimental; basic research.
 (e) This research consisted of a series of investigations concerning the slow motion of axially symmetric solid bodies along the axis of a uniformly rotating fluid.
 (f) Completed.
 (g) The motion of spheres, truncated cylinders, and ellipsoids were studied. The research focused on such phenomena as the terminal speed, wall effect due to the containing cylinder and fluid pushed along by the bodies. In particular, the motion and wall effect on a sphere is quite different than for Stokes' flow.
 (h) Final Report--National Science Foundation, Washington, D.C.
 "Wall Effect on a Sphere in a Rotating Viscous Fluid," P. K. Davis, Proc. ASCE, J. Hydr. Div., 96, HY10, 1970.

- (7644) THE EFFECT OF GEOMETRY AND SPRING DESIGN ON CAVITATION IN DISC-TYPE INLET VALVES USED IN RECIPROCATING PUMPS.
 (b) The Gardener-Denver Company, Quincy, Illinois.
 (c) Philip K. Davis, Assoc. Prof.
 (d) Experimental and theoretical; applied research (Master's thesis).

- (e) The purpose of the research was threefold: (1) to discuss general conditions in flowing fluids that may cause inception of cavitation, (2) to study the cavitation problem in the disc-type valve both experimentally and theoretically, and (3) to develop a basis for spring design that will result in cavitationless performance and rapid closing time.
- (f) Completed.
- (g) Several factors which cause cavitation were found and discussed. Design changes to reduce or eliminate cavitation were suggested.
- (h) "The Effect of Geometry and Spring Design on Cavitation in Disc-Type Inlet Valves Used in Reciprocating Pumps," Delmer H. Landis, Jr., 1968.

(7645)

CHESTOSKY PUMP STUDIES.

- (b) Southern Illinois University Foundation funded by S.I.U. Research and Projects.
- (c) James L. Evers, Asst. Prof.
- (d) Theoretical and experimental; applied research.
- (e) The purpose of this study is to evaluate a variable flow, positive displacement, vane type pump, designed and patented by Mr. Robert Chestosky. In particular, the performance data that is essential in determining the applicability of this device to specific needs are being obtained. Theoretical parameters that can be obtained by considering the pump geometry are also being determined.

(7646)

A MECHANISTIC STUDY OF OXYGEN TRANSFER IN AQUEOUS SYSTEMS.

- (c) Dr. Charles B. Muchmore, Asst. Prof.
- (d) Experimental; basic research; doctoral dissertation.
- (e) A specially treated anion exchange resin was used as an oxygen acceptor in evaluation of oxygen transfer coefficients in an air sparged agitated vessel. The solid phase oxygen acceptor more closely simulates real biological systems such as industrial fermentations or waste treatment activated sludge units than the conventional sulfite method for evaluation of aeration rates. This approach should permit improvement in design and scale-up methods of aeration devices. Variables investigated include agitator rpm, air flow rate, quantity and particle size of the solid phase.
- (g) Most aeration studies of biological systems have assumed a sequential transfer of oxygen through a gas and liquid film at the air-water interface, then through the bulk liquid, and finally through a liquid film surrounding the particle. Results of this study demonstrate the existence of a significant by-pass pathway where oxygen is transferred to the solid particles in the gas-liquid interface region; thereby avoiding the bulk liquid entirely. Thus, aeration rates evaluated by oxygen concentration measurements made in the bulk liquid phase may be in error when a system contains an oxygen absorbing solid phase. Apparent decreases in transfer rates as solids content increases may not be due entirely to changes in fluid properties, as is commonly assumed.
- (h) Doctoral Dissertation, Dept. of Chemistry, Southern Illinois Univ. Library.

SOUTHWEST RESEARCH INSTITUTE, Department of Mechanical Sciences, 8500 Culebra Road, San Antonio, Texas 78228.
H. Norman Abramson, Department Director.

(6063)

STUDIES OF LIQUID PROPELLANTS IN LOW GRAVITY.

- (b) Natl. Aeronautics and Space Admin., Marshall Space Flight Center.
- (c) Dr. F. T. Dodge, Senior Research Engr.
- (d) Theoretical and experimental; applied research.
- (e) Studies of forces on rocket fuel tanks caused by liquid sloshing in simulated low gravity environments.
- (g) Sloshing characteristics for many types of tanks have been studied analytically and experimentally. A novel method of simulating low-gravity by using a magnetic fluid placed in a large solenoidal electromagnet has been developed.
- (h) "Experimental and Theoretical Studies of Liquid Sloshing at Simulated Low Gravity," F. T. Dodge and L. R. Garza, J. Appl. Mech., Trans. ASME, 34, June 1968, pp. 267-273.
"Simulated Low-Gravity Sloshing in Cylindrical Tanks Including Effects of Damping and Small Liquid Depth," F. T. Dodge and L. R. Garza, Proc. 1968 Heat Transfer and Fluid Mech. Inst., pp. 67-79.
"Simulated Low-Gravity Sloshing in Cylindrical, Spherical, and Ellipsoidal Tanks," F. T. Dodge and L. R. Garza, AIAA J. Spacecraft and Rockets, to appear.
"Low-Gravity Fuel Sloshing in an Arbitrary Axisymmetric Rigid Tank," W. H. Chu, J. Appl. Mech., Trans. ASME, to appear. Also, SwRI reports.

(6065)

FLOW-INDUCED VIBRATIONS AND LOSSES IN HIGH VELOCITY DUCT SYSTEMS.

- (b) Natl. Aeronautics and Space Admin., Marshall Space Flight Center.
- (c) Dr. C. Richard Gerlach, Manager, Hydro-Mechanics Systems.
- (d) Theoretical and experimental; applied research.
- (e) Studies of vibration induced in metal bellows and the flow losses in such bellows and in pipe bends.
- (g) An analytical model of bellows flow-induced vibration has been derived and verified. New low-loss elbow has been developed.
- (h) Several SwRI technical reports and one published paper.

(6066)

HYDRODYNAMICS OF RIGID-BODY WATER IMPACT.

- (b) U.S. Naval Ship Res. and Dev. Ctr.
- (c) Dr. C. Richard Gerlach, Manager, Hydro-Mechanics Systems.
- (d) Theoretical and experimental; applied research.
- (e) Studies of real fluid effects in rigid-body water impact, with emphasis on the trapped air cushion; later considerations will emphasize scale effects.
- (g) Have measured effect of liquid properties variations and wave motions on impact pressures.
- (h) Several SwRI technical reports.

(7647)

FLOW-INDUCED VIBRATIONS OF A FLAT PLATE ELASTICALLY SUSPENDED IN A NARROW CHANNEL.

- (b) Bettis Atomic Power Laboratory, Westinghouse Electric Co.
- (c) Dr. F. T. Dodge, Senior Research Engr.
- (d) Theoretical; applied research.
- (e) Investigate simple analytical models of the flow-induced vibrations of nuclear reactor fuel elements and control rods, using hydraulic flow theory.
- (f) Completed.
- (g) Computer program prepared to allow critical flow velocity to be determined for arbitrary geometries and elastic restraints.

(h) SwRI technical report.

(7648)

STUDY AND ANALYSIS OF LOW-G FUEL SLOSHING.

- (b) National Aeronautics and Space Admin., Marshall Space Flight Center.
- (c) Dr. F. T. Dodge, Senior Research Engr.
- (d) Experimental and theoretical; applied research.
- (e) Develop analysis of low-G sloshing in spheroidal and two-dimensional tanks and verify theory by experiments.
- (g) Two-dimensional sloshing analysis and tests completed; computer program for spheroidal tanks underway. Theory compares very well with tests.
- (h) SwRI technical reports; several papers in preparation.

(7649)

EXPERIMENTAL DETERMINATION OF HYDROFOIL FLUTTER SPEED WITH MASS RATIO.

- (b) U.S. Naval Ship Res. and Dev. Ctr.
- (c) Mr. Guido E. Ransleben, Jr., Senior Research Engr.
- (d) Experimental; applied research.
- (e) Four hydrofoil flutter models, identical except for mass ratio, were built and tested in NSRDC water tunnel. Heaviest was 1/2 scale of a model previously tested in high-speed towing facility at NSRDC.
- (f) Completed except for reporting.
- (g) Hydrodynamic damping vs. flow velocity was obtained for heaviest model to approximately 1/2 knot below apparent flutter speed. For the three lighter models, divergence occurred below flutter speed.
- (h) NSRDC technical report (to be issued).

(7650)

LONGITUDINAL TESTING OF PROPELLANT TANK MODELS.

- (b) National Aeronautics and Space Admin., George C. Marshall Space Flight Center.
- (c) Dr. Daniel D. Kana, Senior Research Engr.
- (d) Experimental; applied research.
- (e) Measurements of the natural frequencies of the longitudinal vibration modes of several detailed structural models of launch vehicles containing liquid.
- (h) SwRI technical report.

(7651)

SYSTEMS ANALYSIS AND PRELIMINARY DESIGN OF CAVITATION DAMAGE TEST FACILITY FOR SURFACE-EFFECT-SHIP MATERIALS.

- (b) Joint Surface Effect Ships Program Office, Washington, D.C.
- (c) Dr. H. N. Abramson, Director, and Mr. W. E. Woolam, Senior Research Engr.
- (d) Experimental, theoretical, and field investigation; development.
- (e) Identify areas of cavitation damage on surface effect ships and formulate a preliminary design of a facility to study cavitation effects.

STANFORD RESEARCH INSTITUTE, Menlo Park, California 94025. Charles J. Cook, Executive Director, Physical Sciences.

(7652)

COST ANALYSIS OF SIX WATER DESALINATION PROCESSES.

- (b) Office of Saline Water.
- (c) C. F. Clark.
- (d) Techno-economic analysis.
- (e) Capital and operating costs were determined for

various sized desalting plants and feed waters. Effect on water costs of future changes in important process variables was estimated.

- (f) Completed.
- (g) Indicated application areas for each desalting process.
- (h) "Cost Analysis of Six Water Desalination Processes," C. F. Clark, Stanford Research Inst., Res. and Dev. Rept. No. 495, Office of Saline Water, Nov. 1969.

(7653)

EVALUATION OF PROGRAM FOR SUPPRESSING EVAPORATION FROM RESERVOIRS.

- (b) Bureau of Reclamation.
- (c) P. V. Roberts.
- (d) Applied research and development.
- (e) The project consists of an evaluation of the Bureau of Reclamation's research program aimed at reducing evaporation losses from reservoirs. Emphasis is on technical feasibility of evaporation reduction measures--such as chemical monolayer application--but ecological effects and economic factors are considered as well.
- (g) Project report to be submitted March 1970.

(7654)

SHOCK EFFECTS IN FUEL CELLS.

- (b) McDonnell-Douglas Corp.; Naval Air Systems Command.
- (c) R. F. Williams.
- (d) Experimental, applied research.
- (e) Pressure transducers and high speed cameras were used to investigate the "hydraulic ram" phenomena resulting from penetration of aircraft fuel tanks by tactical caliber projectiles.
- (f) Completed.
- (g) Hydraulic ram loads were found to result from three separate phenomena; (1) shock waves generated by initial impact, (2) incompressible fluid flow around the projectile, and (3) cavitation collapse. Pressure-time measurements at tank walls were obtained for each of these phases.

(7656)

EFFECT OF DYNAMIC PROPERTIES UPON LIQUID DISSEMINATION.

- (b) Edgewood Arsenal, Dept. of the Army.
- (c) David C. Erlich, Physicist, Poulter Lab.
- (d) Experimental, basic research.
- (e) Gas gun experiments are being performed to determine Hugoniot, release adiabats, and dynamic tensile strengths of various liquids uniaxially shocked at high stress rates. Lagrangian foil gages placed in the liquid yield the needed stress histories.

(7657)

BULK CAVITATION IN MONOPROPELLANTS.

- (b) Project Squid, Office of Naval Research.
- (c) Dr. D. C. Wooten.
- (d) Theoretical and experimental.
- (e) Measurement of cavitation initiation and cavity growth behind a single shock produced tension wave in liquids and assessment of the role of cavitation in the production of hot spots behind a shock wave.

(7658)

FLUID JET PRINTER DEVELOPMENT.

- (b) U. S. Post Office Department.
- (c) Steven H. Johnson.
- (d) Experimental and theoretical, development and design.
- (e) Design and development of a printing device which electrostatically deflected ink droplets to

deposit binary machine-readable information on rapidly moving mail pieces.

- (f) Completed.
- (g) A non-contacting printer was developed which expelled 8000 binary characters per second. Printing with excellent registration was achieved on mail moving past the printer 200 ips. Printing ink was fluorescent; resulting codes were machine-readable.
- (h) "Techniques and Media for Encoding Binary Information on Letter Size Mail," G. J. Eilers, C. M. Steele, S. H. Johnson, and T. Hori, Final Report to U.S. Post Office Dept., Bureau of Research and Engrg., Washington, D.C.

(7659)

WING-TIP VORTEX INVESTIGATION.

- (c) Dr. Robert Kiang.
- (d) Theoretical and experimental.
- (e) The persistence of the wing-tip vortex has a major influence upon the air traffic control near the airport. Present research is to study the decay of vortex using a sub-scale model wing. A theoretical study of the scaling effect is being made simultaneously.
- (g) Film and anemometry recordings are made of the decaying vortex. Quantitative results have yet to be reduced.

(7660)

HYDRAULIC PUMP DEVELOPMENT FOR ARTIFICIAL HEART.

- (b) National Heart Institute.
- (c) Peter M. Newgard.
- (d) Theoretical and experimental, development and design.
- (e) Development of electro-hydraulic energy converter for artificial heart applications. Parametric analysis of a family of designs using a variable displacement pump. Choice of design for minimum power losses including power for hydrostatic bearings and fluidic control system.
- (g) Analysis and design completed - Bench Model completed.

STANFORD UNIVERSITY, Department of Civil Engineering,
Hydraulic Laboratory, Stanford, California 94305.
Professor Ray K. Linsley, Executive Head of Laboratory.

(1946)

HYDROLOGIC SYNTHESIS.

- (b) National Science Foundation.
- (c) Professor Ray K. Linsley.
- (d) Theoretical and field research.
- (e) A detailed digital computer model (Stanford Watershed Model) is used to investigate various interactions in the hydrologic cycle.
- (h) "Digital Simulation in Hydrology: Stanford Watershed Model IV," Norman H. Crawford and Ray K. Linsley, Tech. Rept. No. 39, July 1966.
"A Sediment Model on a Digital Computer," Moshe Negev, Dept. of Civil Engrg. Tech. Rept. No. 76, March 1967.
"Hydrologic Effects of Rainfall Augmentation," Alan M. Lumb, Dept. of Civil Engrg. Tech. Rept. No. 116, Nov. 1969.

(3507)

STUDY OF INFILTRATION.

- (b) Federal Water Pollution Control Admin.
- (c) Prof. Joseph B. Franzini.
- (d) Theoretical investigation; laboratory and field studies; basic research; Ph.D. theses.
- (e) An attempt is being made to develop relations

between soil parameters and infiltration capacities. Investigation is being extended to unsteady, unsaturated flow through soils as experienced in capillary rise, drainage and infiltration situations. Various two-dimensional flow problems are under investigation.

- (g) An analytic approach to the solution of unsteady, unsaturated horizontal flow in soils has been developed. If the soil diffusivity is expressible in exponential form, the method permits prediction of soil moisture movement. An analytical method for the solution of unsteady, unsaturated flow from a cylindrical source has been developed. Results show that the flow rate decreases with time. The effect of an applied pressure on horizontal flow in soils has been investigated; the presence of an ever-growing saturated flow region preceded by an enlarging unsaturated zone was predicted and observed.
- (h) "Unsteady Flow in Unsaturated Soils from a Cylindrical Source of Finite Radius," R. Singh and J. B. Franzini, Jour. of Geophys. Research, Vol. 72, No. 4, pp. 1207-1215, Feb. 15, 1967.
"Comments on Unsaturated Flow from a Cylindrical Source," R. Singh and J. B. Franzini, J. Geophys. Res., June 1968.

(4219)

SUPERCAVITATING HYDROFOIL THEORY.

- (b) Naval Ship Research and Development Center.
- (c) Profs. B. Perry and R. L. Street.
- (d) Theoretical; basic research; Ph.D. theses and postdoctoral research.
- (e) Analyses are being made to develop a method for computing the flow about a supercavitating three-dimensional lifting hydrofoil having arbitrary aspect ratio and arbitrary angle of attack.
- (g) Nonlinear solutions for two-dimensional and axisymmetric cavitating flows have been obtained.
- (h) "Techniques for Solving Free-Streamline, Cavity, Jet and Seepage Problems by Finite Differences," R. W. Jeppson, Dept. of Civil Engrg. Tech Rept. No. 68, Sept. 1966.
"Cambered Bodies in Cavitating Flow -- A Nonlinear Analysis and Design Procedure," R. L. Street and B. E. Larock, Dept. Civil Engrg. Tech. Rept. No. 72, Dec. 1966.

(4916)

DISPERSION OF POLLUTANTS IN FLOW THROUGH POROUS MEDIA.

- (c) Profs. E. Y. Hsu and R. L. Street.
- (d) Basic experimental and theoretical research for Ph.D. thesis.
- (e) Study of hydrodynamic dispersion in porous media. Complex variable analysis of flow fields is combined with a convective dispersion equation to define time-space history of pollutant concentrations. Effects of channel boundary shapes and free streamlines on dispersion are to be studied also.
- (f) Completed.
- (g) Conformal mapping techniques have been applied to seepage from channels in two dimensions; the results were verified by experiments. The classic methods of analysis of second-order partial differential equations were used to derive a theory to predict the dispersion of a pollutant solution in a porous media flow; results were correlated with experiments.
- (h) "Studies of Free Surface Flow and Two-Dimensional Dispersion in Porous Media," J. C. Bruch and R. L. Street, Dept. Civil Engrg. Tech. Rept. No. 63, May 1966.

(4917)

MECHANISMS INVOLVED IN WIND-GENERATED WAVES.

- (b) Fluid Mechanics Branch, Math. Sci. Div., Office of Naval Research.
- (c) Profs. E. Y. Hsu and R. L. Street.
- (d) Experimental and theoretical; basic research for doctoral theses.
- (e) Examination, experimental verification, and extension of available theories are being carried out. Several laboratory models of wind-wave phenomena are under study.
- (g) The importance of the shear flow instability mechanism in the transfer of momentum from wind to wave has been established.
- (h) "Flow Over a Moving Boundary in Relation to Wind-Generated Waves," Dept. Civil Engrg. Tech. Rept. No. 60, March 1966. (See also 5454.)

(5453)

STUDIES OF LARGE WAVES.

- (b) Field Projects Branch, Earth Sciences Div., Office of Naval Research.
- (c) Prof. R. L. Street.
- (d) Experimental investigation; master's and Ph.D. project.
- (e) An experimental study of solitary waves is being conducted as a means of establishing the strengths and weaknesses of long wave theory to be used for coastal engineering design.
- (g) It has been concluded that present analytical methods do not adequately represent shoaling solitary waves and current design criteria for breaking heights and run-up of waves need to be revised.
- (h) "An Investigation of the Deformation and Breaking of Solitary Waves," F. E. Camfield and R. L. Street, Dept. Civil Engrg. Tech. Rept. No. 81, Dec. 1967.

(5454)

STUDIES ON WIND-WAVE INTERACTIONS.

- (b) National Science Foundation.
- (c) Prof. E. Y. Hsu.
- (d) Experimental; Ph.D. theses.
- (e) The experiments include pressure, velocity, wave form, and spectral measurements in the region of, and at, the interface. They are designed to study the mechanism of energy transfer between the air and the water.
- (g) At the present time there appears to be a well-argued wave generation theory, yet the data in hand give only qualitative verification of the theory. Order of magnitude disagreement arises between theory and experiment in the case of wave growth rates.
- (h) "Experimental and Analytical Investigation of the Air Velocity Profile Above Progressive Waves," O. H. Shemdin, Dept. Civil Engrg. Tech. Rept. No. 82, July 1967.
- "Spectral Measurements and Growth Rates of Wind-Generated Water Waves," A. J. Sutherland, Dept. Civil Engrg. Tech Rept. No. 84, Aug. 1967.

(6225)

STUDIES OF MASS AND ENERGY TRANSPORT ACROSS AN AIR-WATER INTERFACE.

- (c) Prof. R. L. Street.
- (d) Experimental, laboratory investigation; basic research for Ph.D. dissertations.
- (e) Detailed experimental measurements are to be made to obtain quantitative data on latent and sensible heat transfer and mass transfer due to evaporation and spray formation at an air-water interface.

STANFORD UNIVERSITY, Thermosciences Division, Mechanical Engineering Department, Stanford, California 94305. Professor Stephen J. Kline, Division Director, Professor William M. Kays, Department Chairman.

(6798)

TURBULENT SHEAR FLOWS AND HYDRODYNAMIC STABILITY.

- (b) Mechanics Div., U.S. Air Force Office of Scientific Research; and National Science Foundation.
- (c) Prof. S. J. Kline or Prof. W. C. Reynolds.
- (d) Theoretical and experimental work, primarily fundamental in nature. Includes about six doctoral and three M.S. theses plus work of correspondents.
- (e) Emphasizes investigation of the structure of turbulent shear flows (bound and free) and prediction of their properties. Experimental work emphasizes combined visual and quantitative study of instantaneous structures. Predictive studies include improved boundary layer procedures, prediction of turbulence production via hydrodynamic stability calculations, wave descriptions and other approaches. Work in progress also on free surface waves, waving walls and related shear flow problems.
- (g) Detailed comparison of all available prediction procedures for two-dimensional, incompressible turbulent boundary layers on smooth walls completed in 1968 with cooperation from nearly all active workers in this field. Two volumes summarizing this work now available for purchase from Thermosciences Division. Vol. 1 includes: morphology of theories, details of procedures, systematic comparison of theories with at least sixteen flows of widely varying types, summary and evaluation of results, and extensive discussion of structure problem in turbulent shear flows. Vol. II contains the standardized data and method used in compiling it. Recent data indicate many details of the wall layer models which give rise to turbulence production. These data show that essentially all production arises intermittently during what are called "bursting times." Detailed observations of bursts using bubble marker methods suggest that the mechanism is an intermittent, local instability. Current efforts involve several attempts to provide appropriate mathematical models for this type of flow mechanism.
- (g) Detailed study of the behavior of controlled waves in a fully-established two-dimensional channel flow have been completed. Phase shift and attenuation have been measured for three frequencies and compared with several analytical models.
- (h) Complete list of reports and papers available on request to correspondents. See also (g).

(6799)

FLOW IN SUBSONIC DIFFUSERS.

- (b) General Electric Co., General Motors Corp., Caterpillar Tractor Co., Curtiss-Wright and Boeing.
- (c) Prof. S. J. Kline or Prof. J. P. Johnston.
- (d) Experimental and theoretical investigation of diffuser flows; M.S. theses and dissertations.
- (e) Establishment of flow characteristics including flow regime maps, location of optima for various design criteria, provision of reliable predictive procedures.
- (g) Flow regime maps for "Simple Diffusers" (see below) are established. Optima for a number of cases are thus provided. Calculation procedure for simple cases has been constructed for various geometries and unstalled flow. "Simple Diffuser" is one which: (1) has straight or nearly straight centerline; (2) Mach number less than choking; (3) Reynolds number high enough to give turbulent

boundary layer at or near throat; (4) potential flow in core plus boundary layer at inlet. Flow maps and correlations for one large class of curved units have also been completed. A method for stabilizing flows to very large angles, using vanes, has been established. Current work partially complete, emphasizes extension into "non-simple" cases of several kinds.

- (h) Complete list of reports and papers available on request to correspondents.

(6800)

FLOW IN ROTATING SYSTEMS.

- (b) National Science Foundation.

- (c) Prof. J. P. Johnston.

- (d) Theoretical and experimental; basic; M.S. and Ph.D. theses.

- (e) Fundamental experimental and theoretical investigation in flow in rotating systems with particular emphasis on boundary layer effects. A large rotating apparatus of flexible design is available to study various configurations.

- (g) Fully established flow in a channel can be strongly affected by rotation. On "leading" wall a "super turbulence" is produced; on "trailing" wall relaminarization occurs for sufficiently high values of rotation parameter. Flow regimes have been mapped; see first reference below. Current studies continue work on structure to provide more details and application of stability theory. During 1970-71 studies in rotating-diffused passages and free shear layers are planned.

- (h) "The Influence of Rotation on Flow in a Long Rectangular Channel -- An Experimental Study," R. M. Halleen and J. P. Johnston, Rept. MD-18, Thermosciences Div., Dept. of Mech. Engrg., Stanford Univ., 1967.
"The Laminar Boundary Layer on a Rotating Circular Arc Blade," R. M. Halleen and J. P. Johnston, J. Basic Engrg., Trans. ASME, Vol. 88, Series D, No. 1, March 1966.

(6801)

USE OF HOT-WIRE ANEMOMETER IN WATER.

- (b) Mechanics Div., U.S. Air Force Office of Scientific Research.

- (c) Prof. S. J. Kline or Prof. R. J. Moffat.

- (d) Experimental work primarily.

- (e) Calibration of commercially available instruments for noise and drift completed. Effects of some types of contaminants evaluated. Effects of particle size on drift for several common types of probes established, including levels for essentially drift free operation. Attempts to provide primary calibration for fluctuations in progress.

- (f) Work in (e) nearly complete at Jan. 1, 1970.

- (g) Report to be issued in 1970.

STEVENS INSTITUTE OF TECHNOLOGY, Davidson Laboratory,
Castle Point, Hoboken, New Jersey 07030. Dr. John P. Breslin, Director.

(3516)

INVESTIGATION OF HULL BENDING MOMENTS IN WAVES.

- (b) Ship Structure Committee.

- (c) Mr. Edward Numata.

- (d) Experimental; applied research.

- (e) Models of the cargo ships WOLVERINE STATE and CALIFORNIA BEAR were instrumented to measure vertical and lateral wave bending moments at the same location used aboard ship for strain gage

measurements during actual voyages. The models were run at a range of headings to regular waves with a range of lengths. Prediction of ship bending moments in realistic seas will be made for correlation with bending moment data collected aboard ship.

- (f) Completed.

- (h) "Midship Wave Bending Moments in a Model of the Cargo Ship WOLVERINE STATE Running at Oblique Headings in Regular Waves," and

"Midship Wave Bending Moments in a Model of the Mariner-Class Cargo Ship CALIFORNIA BEAR Running at Oblique Headings in Regular Waves," Ship Structure Committee Reports SSC-201, 202, Sept. and Nov. 1969 (U.S. Coast Guard Headquarters, Washington, D.C.).

(4229)

INTERACTION BETWEEN GRAVITY WAVES AND TURBULENCE FIELDS.

- (b) Office of Naval Research, Dept. of the Navy.

- (c) Prof. Daniel Savitsky.

- (d) Experimental and theoretical; basic research.

- (e) The purpose of this work is to study energy loss processes when gravity waves pass through an intense turbulence field.

- (g) Initial experimental results indicate a substantial wave amplitude attenuation within the turbulence field and an amplification outside the field. The hydrodynamic interference appears to be attributable to scattering, wave refraction (due to the mean flow gradient in the turbulence field), or the development of caustic waves.

(5928)

ROUGH WATER TAKE-OFF RESISTANCE OF HYDROFOIL SHIP HULLS.

- (b) Naval Ship Res. and Dev. Ctr.

- (c) Mr. Edward Numata, Inst. of Tech.

- (d) Experimental; applied research.

- (e) A systematic study of the rough water resistance of hull forms suitable for use with hydrofoils, as a function of wave steepness, and frequency of encounter, with and without a range of foil restoring and damping forces and moments.

- (f) Completed.

- (g) Motion response is shown to vary linearly with wave height, and added resistance to vary linearly with wave slope. High length-beam ratio is shown to reduce calm-water resistance and motions in waves at low speed. At 50% of take-off speed and above, motions and added resistance are independent of length-beam ratio. When automatic control is used to increase the pitch- and heave-damping of the foils, motions are attenuated but there is no effect on added resistance.

- (h) "The Effect of Length-Beam Ratio and Hydrofoil Control on the Take-off Characteristics of Hydrofoil Craft in Regular Head Seas," DL Report 1302, May 1968.

(5932)

HYDROPLANING OF AIRCRAFT TIRES.

- (b) National Aeronautics and Space Admin.

- (c) Dr. I. R. Ehrlich, Mgr., Transportation Research Group and Mr. Gilbert Wray, Research Engr.

- (d) Experimental and theoretical; applied research.

- (e) A systematic experimental study is being made of the various parameters affecting hydroplaning of pneumatic aircraft tires. Model tests are being conducted on the Davidson Laboratory rolling road facility; tires may be mounted above this rolling road so that with the tire mount stationary, the tire behavior may be studied and the tire loads measured as functions of rolling speed. The

model tires are fabricated of polyurethane foam, whose density is varied to simulate variations in pneumatic tire inflation pressure. Static and dynamic tests of these models indicate that they are geometrically similar to the prototype pneumatic tires as they deform under load. A quantitative theoretical description of the hydroplaning phenomenon also is being sought.

- (g) Experiments were made which relate water film thickness, tire size, and applied load to hydroplaning inception speed and rolling restoration speed.

(5935)

UNSTEADY LOADS ON DUCTED PROPELLERS AND NOZZLES.

- (b) Naval Ship Res. and Dev. Ctr.
- (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., Miss W. R. Jacobs, Senior Research Engr., and M. R. Ali, Research Engr.
- (d) Theoretical; applied research.
- (e) To develop a method of determining the unsteady and steady loading on a ducted propeller and its enshrouding nozzle operating in a three-dimensional non-uniform flow field.
- (f) Final report is being prepared.
- (g) Theory demonstrates the filtering effect of the propeller on the flow field so that the direct loading is zero at all frequencies not equal to multiples of blade frequency (i.e., blade frequency times 0, 1, 2 . . .). A computer program adaptable to the CDC-6600 high-speed computer has been developed which evaluates the steady state and vibratory propeller-generated and duct forces and moments on the basis of the unsteady lifting surface theory.
- (h) Davidson Lab. Rept. 1309 in preparation.

(5936)

PROPELLER-SINGING PHENOMENON AS A SELF-EXCITED VIBRATION SYSTEM.

- (b) Naval Ship Res. and Dev. Ctr.
- (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., and Miss W. R. Jacobs, Senior Research Engr.
- (d) Theoretical; applied research.
- (e) To improve the mathematical model introduced in the previous study at Davidson Lab. for the propeller singing phenomenon as a self-excited vibration system and to develop expressions for the acoustic signal produced by the propeller at the singing stage.
- (f) Completed.
- (g) Sound levels calculated by the present theoretical expressions are in good agreement with available experimental results. Apparently the three-dimensional flow field about an operating propeller is dominated at the singing stage by the two-dimensional vortex patterns.
- (h) Davidson Lab. Rept. 1353.

(5937)

PROPELLER-RUDDER INTERACTION.

- (b) Naval Ship Res. and Dev. Ctr.
- (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., Miss W. R. Jacobs, Senior Research Engr., M. R. Ali, Research Engr.
- (d) Theoretical; applied research.
- (e) To evaluate theoretically the loading distribution on a rudder of finite aspect ratio in the presence of a propeller operating in three-dimensional non-uniform flow and to determine the rudder torque and side force.
- (f) Completed.
- (g) Theory demonstrates the filtering effect of the propeller on the harmonic constituents of the wake which results in the rudder operating in a

flow field of frequencies equal to multiples of blade frequency. A numerical procedure adaptable to the CDC-6600 computer has been developed which furnished information about the steady and time-dependent pressure distributions on both lifting surfaces and the resultant hydrodynamic forces and moments. Calculations exhibit the importance of axial clearance, number of blades, and the harmonic components of the hull wake.

- (h) Davidson Lab. Rept. 1284.

(5938)

UNSTEADY LOADS ON A MARINE PROPELLER.

- (b) Naval Ship Res and Dev. Ctr.
- (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., Miss W. R. Jacobs, Senior Research Engr., and Mr. Paul Rank, Research Engr.
- (d) Theoretical; applied research.
- (e) To determine the loading distribution and vibratory thrust and torque on a rotating propeller operating in a non-uniform three-dimensional flow. The resulting integral equation is solved by the mode approach in conjunction with the Glauert lift operator.
- (f) Completed.
- (g) The surface integral equation has been solved by means of the collocation method in conjunction with the generalized lift operator, for a prescribed set of chordwise modes which reproduce the proper leading edge singularity and fulfill the Kutta condition at the trailing edge. General programs have been developed to accommodate any geometry of propeller operating in a specified nonuniform inflow condition for a large but finite number of chordwise modes. The calculations indicate that the spanwise loading distribution and the steady and time-dependent thrust and torque reach stable values after 3 to 5 chordwise modes, but the chordwise distribution does not converge with a small number of modes, particularly in the neighborhood of the leading and trailing edges. A comparison of theoretical and experimental results for the vibratory thrust shows satisfactory agreement on the whole.
- (h) Davidson Lab. Rept. 1133, J. Ship Research, Vol. 12, No. 1, 1968.

(7678)

VISCOUS EFFECTS ON WAVE RESISTANCE.

- (b) Office of Naval Research, Dept. of the Navy.
- (d) Experimental and theoretical; basic research.
- (e) The effect of a free vortex representation of a viscous wake will be calculated according to an empirical technique previously developed. This technique requires measurements to find the location and flux of vorticity at the separation point of the body. These measurements and calculations will be carried out for a thick, large-draft strut.

(7679)

FLOW OVER WAVY SURFACES.

- (b) National Science Foundation.
- (c) Dr. Richard I. Hires, Asst. Prof. of Ocean Engrg.
- (d) Experimental; basic research.
- (e) The purpose of the project is to measure variation in flow parameters over a rigid sinusoidal boundary. Hot-wire measurements of turbulent velocity fluctuations and pressure distribution measurements on the boundary will be taken. Results will be applied to problems of wind-wave generation.

(7680)

WIND-WAVE GENERATION WITH OPPOSING CURRENTS.

- (b) National Science Foundation.
 - (c) Dr. Richard I. Hires, Asst. Prof. of Ocean Engrg.
 - (d) Field investigation; basic research.
 - (e) To study parameters of wind-generated waves with and without an opposing tidal current. Simultaneous observations of wind, waves and current are required to determine current's influence on wave steepness. Work will be done in the Hudson River with wave and current measurements from a bottom-mounted tower.
- (7681)
EXPERIMENTAL INVESTIGATION OF WAVE-CURRENT INTERACTIONS.
- (b) National Science Foundation.
 - (c) Dr. Richard I. Hires, Asst. Prof. of Ocean Engrg.
 - (d) Experimental; basic research.
 - (e) To investigate the interaction of a single-component wave train with a steady but horizontally nonuniform current, with the aim of clearly exposing the importance of the wave radiation stress in wave-current interactions. The work is being conducted in a water channel on which waves are generated pneumatically. Wave heights, lengths, and periods will be measured with two resistance-type wave gauges. Water speed will be determined by using hot-film anemometers.
- (7682)
MOTIONS OF OCEAN PLATFORMS.
- (b) National Science Foundation, Sea Grant Program.
 - (c) Dr. Charles J. Henry, Research Assoc. Prof., Ocean Engineering Department.
 - (d) Experimental and theoretical; basic and applied research.
 - (e) To develop a reliable analytic technique for predicting wave-induced motions of ocean platforms. Computer programs have been developed for predicting motions of barge-type hulls representing floating ocean platforms. The results have been found to be in good agreement with motions measured in model tests in irregular waves. In addition, a series of secondary studies are being carried out to provide basic understanding of (1) wind-generated waves with and without currents, (2) hydrodynamic forces on oscillating cylinders for large amplitude motions, and (3) extreme environmental conditions.
 - (h) "Wave Exciting Forces and Moments on an Ocean Platform Fixed in Oblique Seas," C. H. Kim and F. Chou, 2nd Offshore Tech. Conf., Apr. 1970, Houston, Texas.
- (7683)
MOTIONS OF FLOAT-SUPPORTED CRAFT IN A SEAWAY.
- (b) Naval Air Systems Command.
 - (c) Mr. John A. Mercier, Research Engineer.
 - (d) Experimental and analytical; applied research.
 - (e) Series tests of methodically varied float-supported craft have been carried out in irregular waves, and analyzed to obtain transfer functions and impulse response functions. Analytical methods for computing the motions of arbitrary multi-float platforms, using experimentally determined hydrodynamic force derivatives evaluated for isolated single floats, have been shown to be effective.
 - (f) Completed.
 - (h) "Motions Response of a Related Series of Vertical Float-Supported Platforms in Irregular Seas," J. A. Mercier, Davidson Lab. Rept. 1334, Feb. 1970. "A Method for Computing Float-Platform Motions in Waves," J. A. Mercier, ALAA Paper No. 69-400, 2nd Adv. Marine Vehicles & Propulsion Mtg., May 1969. "Hydrodynamic Forces on Some Float Forms," John A. Mercier, Davidson Lab. Rept. 1407, Oct. 1969.
- (7684)
CRUISING AND HOVERING RESPONSE OF A TAIL-STABILIZED SUBMERSIBLE.
- (b) Special Projects Office, Office of Naval Research.
- (c) Dr. A. Strumpf, Head, Stability & Control Div.
 - (d) Theoretical; applied research.
 - (e) Equations of motion are used to analyze the dynamic stability and limit maneuver response of a tail stabilized submersible in cruising and hovering vertical plane motions. The stability of a submersible with both bow and stern stabilizers also is treated.
 - (f) Completed.
 - (g) This type of vessel can perform adequately in cruising but is subject to highly coupled, unstable hovering motion, especially in stern-to-bow ocean currents. The vessel with both bow and stern stabilizers has inherent hovering stability.
 - (h) "Cruising and Hovering Response of a Tail-Stabilized Submersible," A. Strumpf, J. Hydronautics, Vol. 1, No. 2, October 1967.
- (7685)
SHIP CONTROLLABILITY IN CANALS.
- (b) U. S. Army Engineer District, Jacksonville.
 - (c) Dr. H. Eda and Professor D. Savitsky.
 - (d) Analytical and experimental.
 - (e) To develop a mathematical model on a digital computer, to represent the dynamic behavior of ships in canals and, on the basis of results of digital simulations, to establish a guide to relationships between ship size and acceptable canal dimensions from the ship control viewpoint.
 - (f) Completed.
 - (h) Davidson Lab. Tech. Notes 807, 813, 817.
- (7686)
FEASIBILITY STUDY OF SIMULATORS FOR CANAL PILOT TRAINING.
- (b) Panama Canal Company.
 - (c) Dr. H. Eda, Research Scientist and Prof. D. Savitsky, Asst. Director, Davidson Laboratory.
 - (d) Analytical.
 - (e) To determine the feasibility of developing a computer-based simulator and of using large free-running models in a Panama Canal pilot-training facility.
- (7687)
DIRECTIONAL STABILITY AND SEAKEEPING QUALITIES OF BARGE TRAINS IN COASTAL SEAWAYS.
- (b) Office of Research and Development, Maritime Administration.
 - (c) Dr. H. Eda, Research Scientist.
 - (d) Experimental and theoretical.
 - (e) The objective of the study is to improve the controllability of a tug-barge system in calm water and in coastal seaways, in order to obtain greater productivity and higher operational efficiency.
 - (g) Stability analysis and digital simulation of a pull-towed barge indicate that activated flaps hold promise of improving directional stability without substantial increase in resistance. A computer program has been developed for predicting the lateral bending moment on the two connections of the barge-train in quartering seas. Predicted results compare favorably with test results. Results indicate that the lateral bending moment in quartering seas can be the most important component in the resultant force on the tow connections of barge trains in waves. Resistance test results for barge systems have been prepared, with discussion of the effect of loading conditions, skeg configurations, number of barges, and head seas.
 - (h) "Resistance and Directional Stability of Barges in a Coastal Seaway," H. Eda, Davidson Lab., Rept. 1303. "Studies of Barge Trains in a Coastal Seaway,"

(7688)

PROPELLER LOADING DISTRIBUTIONS.

- (b) Naval Ship Res. and Dev. Ctr., Dept. of the Navy.
- (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., and Miss W. R. Jacobs, Senior Research Engr.
- (d) Theoretical; applied research.
- (e) To improve the numerical procedure for evaluating propeller loading which had been developed at Davidson Lab. by adapting unsteady lifting surface theory.
- (f) Completed.
- (g) A new approach, based on the fact that the assumed Birnbaum chordwise modes are not linearly dependent, has achieved stability for the chordwise distribution. Other refinements of the numerical program have improved the accuracy of both chordwise and spanwise loading distributions and brought the theoretical results closer to experiment.
- (h) Davidson Lab. Rept. 1319, J. Ship Research, Vol. 13, No. 4, 1969.

(7689)

COUNTERROTATING AND TANDEM PROPELLERS OPERATING IN SPATIALLY VARYING, THREE-DIMENSIONAL FLOW FIELDS.

- (b) Naval Ship Research and Development Center, Dept. of the Navy.
- (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., and Miss W. R. Jacobs, Senior Research Engr.
- (d) Theoretical; applied research.
- (e) To study two interacting propellers of either a counterrotating or a tandem propulsive system when both lifting surfaces operate in spatially non-uniform flow.
- (f) Completed.
- (g) A mathematical model is introduced which represents as realistically as possible the geometry of the propulsive system and the three-dimensional spatially varying inflow conditions. The two surface integral equations which describe the interaction problem for each system are solved by the generalized lift operator method used in conjunction with the mode-collocation approach. The mathematical analysis has been brought to the point where the suggested numerical procedure can be programmed.
- (h) Davidson Lab. Rept. 1335.

(7690)

PROPELLER-INDUCED VIBRATORY PRESSURE MEASUREMENTS.

- (b) Naval Ship Systems Command.
- (c) Mr. John A. Mercier, Research Engr.
- (d) Experimental; applied research.
- (e) To develop a measuring technique for determining propeller-induced blade frequency pressures on ship model hulls and to evaluate the net vibratory forces on the hull from these pressures.
- (g) A measuring system has been developed and applied to a model in a circulating water channel. The apparatus is being modified for handling large quantities of data in towing-tank tests.
- (h) Davidson Lab. Rept. 1321 (obtain from Defense Documentation Center, Cameron Sta., 5010 Duke St., Alexandria, Va. 22314. AD 686-404).

(7691)

PROPULSION OF DEEP SUBMERGENCE VEHICLES.

- (b) Commercial client.
- (c) Mr. John A. Mercier, Research Engr.
- (d) Experimental; development.
- (e) Results of model tests on two alternative hull configurations are given.
- (f) Completed.

- (h) "Design Aspects of Stern-Mounted Propellers for Deep Submergence Vehicles," John A. Mercier, J. Hydronautics, Vol. 4, No. 2, 1970.

(7692)

GENERALIZED LIFT OPERATOR TECHNIQUE FOR THE SOLUTION OF THE DOWNWASH INTEGRAL EQUATION.

- (b) Naval Ship Res and Dev. Ctr., Dept. of the Navy.
- (c) Miss W. R. Jacobs, Senior Research Engr., and Dr. S. Tsakonas, Head, Fluid Dynamics Div.
- (d) Theoretical; applied research.
- (e) To solve the downwash integral equation by a more accurate method than the generally used mode-collocation method.
- (f) Completed.
- (g) The new method developed for solution of lifting-surface problems employs a "generalized lift operator" technique which is found to be a more accurate, versatile, and rapid procedure for inverting the downwash integral equation than the generally used "mode-collocation" method. The new technique allows the chordwise integration to be carried out analytically, thereby avoiding the difficulties of the other method. This new approach has been applied to several two-dimensional, unsteady airfoil problems to demonstrate compatibility with known explicit solutions. Numerical solutions for two rectangular foils of aspect ratio 1 and 2 show good agreement with experiment and fit in with known trends.
- (h) Davidson Lab. Rept. 1308, J. Hydronautics, Vol. 3, No. 1, 1969 (published as "A New Procedure for the Solution of Lifting Surface Problems").

(7693)

SMOOTH-WATER PERFORMANCE OF A SURFACE PIERCING HYDROFOIL BOAT.

- (b) Office of Naval Research, Dept. of the Navy.
- (c) Dr. A. Strumpf, Head, Stability and Control Div.
- (d) Experimental and theoretical; applied research.
- (e) To formulate the nonlinear differential equations of motion in six degrees of freedom for a surface piercing hydrofoil boat operating in smooth water; determine the values of the hydrodynamic parameters by rotating-arm experiment and theory; obtain digital computer solutions of the motion equations for the steady straight and turning flight characteristics, dynamic stability indices, and trajectory in entering a turn under unventilated flow conditions.
- (f) Completed.
- (g) The experimental results show strong bow-to-stern foil interactions causing either stern foil ventilation or large reductions in stern foil vertical force. Steady turning capability of the hydrofoil craft is shown to be poor compared with a surface ship or submersible. Computed trajectory does not indicate any marked yaw-to-pitch coupling effects in uncontrolled entry into a steady turn.
- (h) Davidson Lab. Rept. 1264.

(7694)

FORCE MEASUREMENTS ON A ROTATING VARIABLE SWEEP HYDROFOIL WITH CAVITATION AND VENTILATION.

- (b) Naval Air Systems Command.
- (c) Mr. John A. Mercier, Research Engr.
- (d) Experimental; applied research.
- (e) To study the influence of low ambient pressure on the performance of a variable sweep, variable angle-of-attack model hydrofoil.
- (f) Completed.
- (g) Foil performance, including forces and cavitation or ventilation inception, is not influenced by the unsteadiness associated with changes in sweep and attack angle for the relatively slow rates

- used in the present study. Lift versus drag characteristics for a hydrofoil-strut system may be favorably affected by the sweep and attack angle for some values of lift coefficient, C_L .
- (h) Davidson Lab. Letter Rept. 1332 (obtain from Defense Documentation Center, Cameron Sta., 5010 Duke St., Alexandria, Va. 22314. AD 681-021).

(7695)

ISOLATION OF SHIP FOREBODY WAVE RESISTANCE.

- (b) Naval Ship Systems Command.
 (c) Mr. John A. Mercier, Research Engr.
 (d) Experimental; basic research.
 (e) To attempt to isolate the contribution of the forebody of a ship to the wave resistance.
 (f) Completed.
 (g) The experimental technique for measuring the forebody hydrodynamic force was judged successful. No conclusions concerning wave-making resistance were possible.
- (h) Davidson Lab. Rept. 1359 (obtain from Defense Documentation Center, Cameron Sta., 5010 Duke St., Alexandria, Va. 22314. AD 696-652).

(7696)

PLANING SURFACES WITH WARP AND FLAPS.

- (b) Office of Naval Research, Dept. of the Navy.
 (c) Mr. P. Ward Brown, Mgr., Marine Craft Development Group.
 (d) Experimental and theoretical; applied research.
 (e) The forces, moments, and wetted areas of planing surfaces that have warped bottoms and are equipped with transom flaps have been determined; and existing planing formulae are being modified to account for the effects of warped deadrise and of flaps.

(7697)

LOW-SPEED PLANING.

- (b) Office of Naval Research, Dept. of the Navy.
 (c) Mr. P. Ward Brown, Mgr., Marine Craft Development Group.
 (d) Experimental; applied research.
 (e) A study is being made of the performance of power boats in the hump region both in smooth water and waves. The intention is to develop an understanding of the mechanics of the low-speed resistance hump with a view to improving the performance of heavily loaded hulls. A series of hulls developed from Series 62 is being tested.

(7698)

ROUGH WATER PERFORMANCE OF PLANING BOATS.

- (b) Naval Res. and Dev. Ctr., Dept. of the Navy.
 (c) Mr. G. Fridsma, Research Engr.
 (d) Experimental and theoretical; applied research.
 (e) A systematic study of the performance of planing boats in irregular waves. The effect of changes in hull geometry, including length-beam ratio, deadrise, and bow form as well as load is being studied from low speed through hump to planing speed. Loads and motions are being measured and analyzed statistically.
 (g) High-speed response to waves has been found to be significantly nonlinear.

(7699)

MODEL TESTS OF THE LOCKHEED AIR-SEA CRAFT.

- (b) Office of Naval Research, Air Programs Naval Application and Analysis Group.
 (c) Mr. Gerard Fridsma, Research Engr.
 (d) Experimental and theoretical; applied research.
 (e) A 1/25-scale model of the Lockheed Air-Sea Craft was built and tested to determine its landing and take-off characteristics in smooth water and in

irregular waves. The hydrodynamic configuration was optimized by a computer study and by smooth-water constant-speed tests, which developed the size, location, and angles of attack of the planing surfaces for stable operation. Static and dynamic loads as well as the motions of the craft were measured, over a range of operating conditions, in tests conducted with a yawed model and in tests involving model take-offs and landings up to sea state 5.

(f) Completed.

- (g) The results indicate the Air-Sea Craft to be a feasible and practical vehicle for carrying out the ASW mission.

(7700)

HYDRODYNAMICS OF AIRCRAFT TIRE HYDROPLANING.

- (b) National Aeronautics and Space Admin.
 (c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., Dr. C. J. Henry, Division Chief, Marine Systems Division, and Miss W. R. Jacobs, Senior Res. rch Engr.
 (d) Theoretical; applied research.
 (e) To obtain a theoretical description of the aircraft tire hydroplaning phenomenon.
 (f) Completed.
 (g) An approximate theory has been developed for a study of the hydroplaning tire by considering it as a planing surface of small aspect ratio in extremely shallow water. The results of this approximation exhibit hydrodynamic behavior similar to that of hydroplaning pneumatic tires and thus indicate that the phenomenon can be described from the standpoint of inviscid hydrodynamics. The analysis furnishes families of curves which can be considered to represent, qualitatively, the start of hydroplaning and thus give qualitative guidance for avoiding the undesirable hydroplaning condition.
- (h) Davidson Lab. Rept. 1238, NASA CR-1125.

(7701)

HIGH-SPEED WHEELED AMPHIBIANS.

- (b) Office of Naval Research, Dept. of the Navy.
 (c) C. J. Nuttall, Jr., President, WNR, Inc., Chestertown, Md., or I. O. Kamm, Asst. Mgr., Transportation Research Group, Davidson Lab., Stevens Inst. of Tech.
 (d) Experimental, theoretical; applied research.
 (e) This project summarizes a design study on high-speed logistical amphibians, conducted for the United States Army Ordnance Corps between 1956 and 1959 with the objective of (1) developing test data, (2) conducting an engineering and operational study of high-speed wheeled amphibious vehicles, and (3) suggesting promising design concepts from the results. Extensive hydrodynamic towing-tank tests were performed on models with planing hull shapes and on the vehicle train concept. Based on these model tests and operational considerations, six basic design concepts were drawn.
 (f) Completed.
 (g) Planing amphibious trucks (5- to 20-ton payload), capable of maximum still-water speeds in the order of 30 mph, are technically feasible; but their complexity and cost are such that they cannot replace the state-of-the-art workhorse amphibians. Improvement in cargo handling at ship-side appears to offer a more dramatic time-saving than increased water speed, in an over-the-beach unloading operation using amphibians. Such improvement becomes even more important to the economics of a high-speed amphibian system. It is recommended that any further research of high-speed amphibians

be done only under the full realization that such machines represent special-purpose vehicles fulfilling only limited operational requirements. There is no hope that such craft will ever replace the present state-of-the-art displacement-type amphibian.

- (h) "High-Speed Wheeled Amphibians, A Concept Study," C. J. Nuttall, Jr. and Irmin O. Kamm, Davidson Lab. Rept. 726-1, prepared for Office of Naval Research, Dept. of the Navy (Contract Nonr263-69), 84 pp., 60 figs.
"Reports on Hydrodynamic Model Tests of High-Speed Wheeled Amphibian Concepts," Davidson Lab. Rept. 726-11, 212 pp.

(7702)

DEVELOPMENT OF TECHNIQUES FOR THE EVALUATION OF VE- HICLE PERFORMANCE IN SURF.

- (b) U.S. Army Tank-Automotive Command.
(c) Mr. I. O. Kamm, Asst. Mgr., Transportation Research Group.
(d) Experimental; field investigation, development.
(e) Establish and test quantitative means of interpreting and generalizing vehicle performance test in surf, identifying the controlling vehicle and surf parameters and developing means for measuring them. The study seeks to develop techniques for describing the vehicle-surf interaction, to define and classify surf in engineering terms applicable to vehicle control, and to investigate the feasibility of employing scale-modelling techniques.
(g) A series of field tests was performed in which vehicle motions and wave characteristics were measured and photographically recorded simultaneously. Results from on-board instrumentation and the photographic records of Cine-Theodolite tracking cameras will be compared in an effort to determine input-output relationships between vehicle and surf, to determine wave characteristics, and to develop scale modeling techniques. Data analysis to date indicates that the information obtained is satisfactory for the intended purpose. The basic approach is sound; the analysis is continuing.
(h) First and Second Quarterly Progress Reports submitted to U.S. Army Tank-Automotive Command.

(7703)

A MODEL STUDY OF THE HYDRODYNAMIC CHARACTERISTICS OF A SERIES OF PADDLE WHEEL PROPULSIVE DEVICES FOR HIGH- SPEED CRAFT.

- (c) Department of Defense (Project Themis).
(c) Mr. Gilbert Wray, Research Engr., Transportation Research Group.
(d) Experimental and theoretical; applied research.
(e) A systematic study is being made of the various parameters affecting the propulsion characteristics of a high-speed radial-bladed paddle wheel. Model tests are being performed in the Davidson Laboratory "variable pressure free surface" water channel. A model paddle wheel is mounted behind a planing hull, in the water channel, and instrumented to record thrust, torque, and wheel speed. Water velocity in the channel is independently recorded.
Thrust, torque, and wheel speed are measured for a series of wheel-blade immersion depths and water velocities. The effect of changing the number of blades on the wheel is obtained by repeating the above with a model wheel having a different number of blades. From this experimental data, performance characteristics for this type of wheel may be obtained.
(g) Performance curves were obtained relating the effects of blade immersion depth, wheel speed,

slip, wheel advance velocity and number of blades on wheel thrust, input torque and propulsive efficiency.

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Aerospace Engineering, Knoxville, Tennessee 37916.
Dr. J. F. Bailey, Department Head.

(7704)

BASIC RESEARCH IN DYNAMIC SEALING.

- (b) Office of Naval Research, Washington, D.C.; NASA, Lewis Research Center.
(c) William K. Stair, Professor.
(d) Basic research in fluid mechanics as applied to thin films in bearings and seals in laminar and turbulent flow. Research work is conducted with the M.S. and Ph.D. programs of the various co-operating departments.
(e) Theoretical and experimental studies of thin film fluid flow in mechanical face seals, buffered bushing seals, porous wall channels, viscoseals, and labyrinth seals. Problems of cavitation and non-Newtonian effects are included.
(h) "Effect of Groove Geometry on Viscoseal Performance," William K. Stair, J. Engr. for Power, ASME Trans., Series A, 89, 605-614, Oct. 1967.
"Rarefied Gas Flow Through Passages with Static Boundaries," Mancil W. Milligan, ASLE Trans., 11, 228-234 (1968).
"On Gas Ingestion and Fluid Inertia Effects in Viscoseals," Charles F. Fisher, Jr., and William K. Stair, ASLE Special Publ. SP-2, 62-71 (1969).
"Visco-Type Gas Sealing," J. W. Hodgson and M. W. Milligan, ASLE Special Publ. SP-2, 83-87 (1969).
"Fixed Clearance Seals Using Viscosity Effects of Sealed Fluids," A Review; William K. Stair (with Thomas H. Koenig, Ed.), ASLE Special Publ. SP-2, 40-41 (1969).
"Application of Boundary Layer Concepts to Turbulent Lubrication Theory of Bearings and Seals," William T. Snyder and William K. Stair, Fifth Southeastern Conf. on Theor. and Appl. Mech.
"A Note on Flow Over a Flat Plate," Arsev H. Eraslan and John A. Benek, Fifth Southeastern Conf. Theor. and Appl. Mech.
"Further Experiments on the Turbulent Viscoseal," William K. Stair, Charles F. Fisher, Jr., and Larry H. Luttrull, Dec. 1969. For Annual Meeting of ASLE, May 1970.
"The Design and Construction of a Facility to Determine the Dynamics of a Face Seal," Michael R. Headrick, Univ. of Tennessee, M.S. thesis, 120 pages, Dec. 1968.
"Laminar Flow in Plane Channel and Annulus with One Wall Porous," Ming S. Tsai, Univ. of Tennessee, M. S. Thesis, 125 pages, Dec. 1968. Published as Rept. No. EM 68-12-1; DDC AD-682 495.
"An Experimental Study of the Viscoseal Bearing," Chandrakant Khumaji Shah, Univ. of Tennessee, M.S. thesis, 63 pages, Feb. 1969. Published as Rept. No. ME 69-T57-2; DDC AD-686 175.
"Investigation of Laminar Flow Patterns and Pressure Generation in a Viscoseal Geometry," Jan P. B. Vreeburg, Univ. of Tennessee, Ph.D. dissertation, 96 pages, March 1969. Published as Rept. No. ME 69-T57-3; DDC AD-687 720.
"Observations on a Viscoseal in a Transparent Housing - The Prevention of Leakage and Breakdown," R. J. Boon, A Translation by J. P. B. Vreeburg, 102 pages, March 1969, Univ. of Tennessee Rept. No. ME 69-T57-4; DDC AD-693 107.
"An Analysis of the Viscoseal Bearing," Walter Lindell Roberts, Univ. of Tennessee, M.S. thesis,

93 pages, May 1969. Published as Rept. No. ME-T57-5; DDC AD-689 546.

"An Investigation of Interface Stability and its Relation to Gas Injection in Viscoseals," Charles F. Fisher, Jr., Univ. of Tennessee, Ph.D. dissertation, 68 pages, Aug. 1969. Published as Rept. No. ME 69-T57-6; DDC AD-696 191.

"Wear Reactions Occurring at the Faces of Mechanical Face Seals in the Boundary Lubrication Condition," David Keith Matthes, Univ. of Tennessee, M.S. thesis, 99 pages, Dec. 1969. Published as Rept. No. ME 69-T57-7.

"The Design and Calibration of Capacitance Transducers," Sherrell T. Myrick, Jr., Univ. of Tennessee, M.S. thesis, 110 pages, Dec. 1969. Published as Rept. No. ME 69-T57-8.

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College Station, Texas 77843. Dr. John B. Herbich,
Professor and Head, Hydraulic Engineering, Fluid
Mechanics and Coastal and Ocean Engineering Division.

(3086)

INVESTIGATION OF DESIGN CRITERIA OF SPUR DIKES.

- (b) Texas A and M University.
- (d) Experimental and analytical.
- (e) A spur dike has been defined as a projection extending upstream from bridge abutments. The project has been divided into five phases: (1) literature survey; (2) analytical study; (3) experimental study in fixed-bed models; (4) experimental study in movable-bed models; (5) review of design criteria for spur dikes.
- (f) Phases (1), (3) and (4) completed, phase (2) re-activated, phase (5) active.
- (g) Preliminary investigations indicate that properly designed spur dikes produce uniform velocity between abutments and are extremely effective in reducing scour at the abutments.
- (h) "Hydraulics of Bridged Waterways," J. W. Delleur, John B. Herbich, E. M. Laursen, D. E. Schneible, and H. J. Tracy, Final report of the Task Committee on Hydraulics of Bridges of the Hydraulics Division, American Society of Civil Engineers, March 1969.

(4155)

EFFECTS OF SLOPE ROUGHNESS ON REGULAR AND IRREGULAR WAVE RUN-UP ON COMPOSITE SLOPES.

- (b) Coastal Engineering Research Center; U.S. Army Engineer District, Galveston; and Texas A&M University.
- (c) Dr. John B. Herbich; Jerry L. Machemehl.
- (d) Experimental and analytical; applied research; doctoral dissertation.
- (e) The objectives are: (1) to investigate the effects of roughened slopes on regular and irregular wave run-up on composite beach sections; (2) to investigate energy losses in the uprush zone due to breaking and bottom dissipation; (3) to determine the effects of roughness on the velocity distribution in the uprush zone; (4) to compare regular and irregular wave run-up on roughened slopes with wave run-up on smooth impermeable slopes; (5) to verify existing equations for determination of height of wave run-up; and (6) to develop semi-theoretical equations for wave run-up.
- (f) Parts e(1), e(4), and e(5) completed; parts e(2), e(3) and e(6) active.
- (g) Agreement between equations and experiments is good for width of berm to wave length ratios

equal to or less than 0.15; roughness elements (steps) reduce wave uprush by a factor of 0.7.

- (h) "Effect of Berm on Wave Run-Up on Composite Beaches," John B. Herbich, R. M. Sorensen and J. H. Willenbrock, Proc. ASCE, J. Waterways and Harbors Div., Paper No. 3526, WW2, May 1963.

(5552)

SCOUR OF FLAT SAND BEACHES DUE TO WAVE ACTION.

(See also 5552A page 65, Lehigh University.)

- (b) Texas A and M University.
- (c) Dr. John B. Herbich; Dr. R. M. Sorensen.
- (d) Experimental and theoretical.
- (e) Erosion of sand beaches due to oscillatory water particle motion of non-breaking waves is of importance where such a beach is fronted by a sea wall supported on spread foundation. Laboratory study was conducted in a two-dimensional wave channel for a Master's thesis.
- (g) The comparison between theoretically calculated values and experimental results indicates fairly good agreement. Model experiments indicate that depth of scour depends to a large extent on wave characteristics and that scour length (distance between scour troughs or crests) is independent of time, but is a function of incident wave length.
- (h) "Scour of Flat Sand Beaches Due to Wave Action in Front of Sea Walls," John B. Herbich, H. D. Murphy and V. Van Weele, Coastal Engrg., ASCE, Ch. 29, 1966.
- "Beach Scour at Seawalls and National Barriers," J. B. Herbich, presented at ASCE National Meeting, New Orleans, La., Feb. 1969.

(6398)

LARGE-SCALE ROUGHNESS IN OPEN-CHANNEL FLOW.

- (b) Texas A and M University.
- (d) Theoretical and experimental.
- (e) The most common measures of open-channel roughness, namely Manning's n and Chezy's C , are predicted from experience. The study ranges from submerged flow in which the height of roughness elements varied from 0.53 to 1.0 times the depth to submerged flow in which elements protruded through the surface. The project has been divided into three phases: (a) subcritical flow, (b) supercritical flow, (c) design applications.
- (f) Phase (a) completed, phase (b) active, phase (c) suspended.
- (h) "Large-Scale Roughness in Open-Channel Flow," John B. Herbich, Sam Shulits, Proc. ASCE, J. Hydr. Div., Paper 4145, HY6, Nov. 1964.

(6399)

TRANSITIONS IN SUPERCRITICAL OPEN CHANNEL FLOW.

- (b) Texas A and M University.
- (d) Theoretical and experimental, Master's thesis.
- (e) In supercritical open channel flow, changes in wall direction (or any other disturbance in the channel) will set up standing waves which may materially affect the flow profile and the entire character of the flow. There is a need for basic information leading to better design of transitions in supercritical flow. Theoretical analysis of the effects of disturbances on supercritical flows in an inclined channel based on the method of characteristics was proposed. The project has been divided into three phases (a) theoretical analysis, (b) experimental verification, and (c) study of application to open channel design.
- (f) Phase (a) completed, phase (b) active, phase (c) suspended.
- (h) "Transitions in Supercritical Open-Channel Flow," Gurnarr Bagge, John B. Herbich, Proc., ASCE, J. Hydr. Div., Paper No. 5417, HY5, Sept. 1967.

"Supercritical Flow through Trapezoidal Expansions," Peter Walsh, Sept. 5, 1968.

(6400)

EFFECT OF ENGINEERING PROJECTS ON QUALITY CHANGES IN SURFACE WATERS.

- (b) Texas A and M University.
- (d) Basic research.
- (e) There are many water quality problems which were either overlooked or considered of no importance in planning many engineering projects in the past. Some of these problems pertaining to hydraulic engineering are (a) effect of dams and other barriers, (b) effect of tidal power plants, (c) effect of underwater dams or sills in a tidal river, (d) effect of steam electric power plants, etc. Accumulation of information and evaluation of the effect of engineering works is proposed.
- (h) "Quality Changes in Surface Waters Caused by Engineering Projects," John B. Herlich, presented at Intl. Conf. on Water for Peace, Washington, D.C., May 1967.

(7705)

VEHICLE-PAVEMENT INTERACTION STUDY.

- (b) Texas Highway Dept. and Federal Highway Administration.
- (c) Dr. Robert E. Schiller, Jr.
- (d) Field investigation; applied research.
- (e) It has been known for many years that low friction coefficients between tires and pavements occur when the pavements are wet. On pavements, with the combination of rough surfaces together with the disturbing effect of raindrops, the water flow is generally turbulent. Laboratory tests are then required to determine the water depths resulting from rainfall on various types of pavement surfaces. The proposed testing program will cover several types of pavement surfaces, using the U.S. Forest Service type F nozzles to simulate rainfall.

(7706)

FORCES DUE TO WAVES ON SUBMERGED STRUCTURES.

- (d) Theoretical and experimental; basic research; Master's thesis.
- (e) The objective is to study the forces due to gravity waves on submerged structures for various shaped structures, water depth and wave lengths using a two-dimensional wave tank and models suspended from load cells.
- (g) There were six models and three water depths used. Approximately 100 runs were made for each model. The relationship between measured vertical and horizontal force and various wave parameters is shown. These results are presented as graphs in dimensionless form. Inertial coefficient (C_M) and drag coefficient (C_D) are evaluated by comparing measured forces to computed forces.
- (h) "Forces Due to Waves on Submerged Structures - Theory and Experiment," John B. Herlich and George E. Shank, Proc. Offshore Technology Conf., Houston, April 1970.

(7707)

USE OF REMOTE SENSING FOR DETECTING SEDIMENT MOTION ALONG THE COAST AND CHANGES IN COASTLINES.

- (b) National Aeronautics and Space Admin.
- (d) Theoretical and field investigation; basic research.
- (e) The objective of this study is to determine the capability of improving the analysis of the coastal processes of erosion and sedimentation using high-altitude remotely sensed data from the manned or un-manned satellites. Orbital re-

mote sensors offer the opportunity for the first time to obtain repeated, synoptic coverage and permits comparisons of large coastal areas. At present such comparisons are possible only with data which are extended over many months, thus seasonal variations are unrecognizable. Photographic flights by the conventional aircraft are also being analyzed.

- (g) Comparisons of the lower level airplane flights with actual field data obtained by the U.S. Coast and Geodetic Survey reveal a good correlation when conventional color photography is used. Depth penetration appears to be a limiting factor.
- (h) "Sediment Motion along the Coast and Changes in Coastlines," John B. Herlich, Zeltan L. Hales, Proc. First Annual Remote Sensing Conference for Recreation and Resource Administrators, Texas A&M Univ., Dec. 1969 (in printing).

(7708)

SCOUR OF GULF COAST SAND BEACHES DUE TO WAVE ACTION IN FRONT OF SEAWALLS AND DUNE BARRIERS.

- (b) National Science Foundation Sea Grant Program.
- (c) Dr. Robert E. Schiller, Jr.
- (d) Experimental, field investigation; applied research.
- (e) As the Texas Coast is developed in the future for industry, recreation, and other uses, the planners will be faced with many decisions involving beaches along the coastline and it is imperative that these planners have a better understanding of the processes of beach scour. Preliminary studies have indicated that the ultimate depth of scour is a function of wave height, and that the location of scour is a linear function of wave length. Other variables that probably affect scour depth are grain size of beach material, barrier inclination and wave reflections from the barrier. The problem appears to be quite complex and thus requires a comprehensive study, both analytical and experimental. The analytical and laboratory studies are to be conducted during the first year of the project, and collection and analysis of field data are to be carried out during the second and third year of the project. The laboratory studies are to be conducted in the 2-foot wide x 3-foot deep x 120-foot long wave channel in the Texas A&M University Hydromechanics Laboratory.
- (h) "Scour of Sand Beaches in Front of Seawalls," John B. Herlich and Stephen C. Ko, Proc. 11th Conf. on Coastal Engrg., London, England, Sept. 1968.

(7709)

ASSESSMENT OF THE COST EFFECTIVENESS OF THE WATER RESOURCES SCIENTIFIC INFORMATION CENTER (WRASIC) SERVICES.

- (b) Office of Water Resources Research, U.S. Dept. of Interior.
- (c) Mr. E. B. Smith.
- (d) Field investigation; applied research.
- (e) The study was conducted to assess the monetary value and acceptability to users of the Selected Water Resources Abstracts Journal (SWRA) and the Selective Dissemination of Information (SDI) System. The results indicate that WRASIC is providing a useful and valuable service to those users who are active in the area of water resources. Comments received from the participants should provide information which will be of assistance in improving future services.
- (f) Completed.
- (h) "Requirements for Effective use of the Water Resources Scientific Information Center (WRASIC) - Determined by Field Evaluation," Volume I, II and

(7710)

REQUIREMENTS FOR EFFECTIVE USE OF THE WATER RESOURCES SCIENTIFIC INFORMATION CENTER (WRSIC) - DETERMINED BY FIELD EVALUATION.

(b) Office of Water Resources Research, U.S. Dept. of Interior.

(d) Field investigation; applied research; Master's thesis.

(e) A field evaluation study of user requirements for effective use of the Water Resources Scientific Information Center (WRSIC) is described. The study included several components including an analysis of potential users classified by their participation in various aspects of water resources; determination of WRSIC user needs according to the type of user; determination of the cost user may pay for services and quality of service demanded; kinds of information that should be included in WRSIC; type of service requirements of potential users; and potential input to WRSIC by users. Total number of organizations interviewed by mail and by personal visits was 726 and total number of persons interviewed was 128, mail questionnaires were sent to 669 participants and the response was 52.9 percent. The results of the study are summarized in graphical and tabular form.

(f) Completed.

(h) See (7709).

(7711)

INTERACTION OF WAVES WITH SUBMERGED OBJECTS.

(c) Dr. C. J. Garrison, Assistant Professor.

(d) Theoretical and experimental; basic research; Ph.D. dissertation and Master's thesis.

(e) The objective is to study the interaction of waves with rigid fixed objects submerged in finite depth of water. The analysis uses numerical methods.

(g) The potential flow problem corresponding to the interaction of waves with rigid submerged objects of arbitrary size and shape is set up. Detailed analysis is carried out for an object having the shape of a semi-ellipsoid. A numerical program is developed for an ellipsoid that is circular in plan form. Numerical results for the pressure distribution, forces and moments obtained from this approach for a hemisphere are compared with the results. The results are encouraging.

(h) "Wave Interaction with Large Submerged Objects," C. J. Garrison, V. Seetharama Rao, and R. H. Snider, Proc. Offshore Technology Conf., Houston, April 1970. Also presented at the ASCE Structural Engrg. Meeting, Portland, Oregon, April 1970 (available as a preprint).

(7712)

NUMERICAL CALCULATION OF WAVE REFRACTION BY DIGITAL COMPUTER.

(b) National Science Foundation Sea Grant Program.

(d) Theoretical; applied research; M.S. thesis.

(e) The objective of this project is to evaluate a method of calculating wave refraction in shoaling waters by numerical analysis as proposed by the Laboratoire National d'Hydraulique du Centre de Recherches et D'Essais de Chatou, France. The purpose of the project is to construct a mathematical model that will predict wave power distribution and wave height variation caused by refraction.

A computer program was developed that will calculate the variations in the wave refraction process in regions having either simple or complex underwater topographies.

(h) "Numerical Calculation of Wave Refraction from Shorelines by Digital Computer," Terry E. Orr and John B. Herbich, Offshore Technology Conf., Houston, April 1970.

(7713)

HEAVY DUTY OIL CONTAINMENT SYSTEM PNEUMATIC BARRIER.

(b) United States Coast Guard, Dept. of Transportation

(d) Experimental; applied research.

(e) The object of the study is to determine if a pneumatic system through which air is released from a submerged pipe can create horizontal surface currents of sufficient magnitude to contain large quantities of oil under adverse sea state conditions. The study is extremely broad in scope and encompasses the following investigations: (1) problem definition, (2) oil set-up by wind and current, (3) hydrodynamics of the pneumatic system, (4) pneumatic supply requirements, (5) system studies and plans (logistics) involving storage, delivery, deployment, mooring, maintenance, retrieval and reliability; and (6) pneumatic barrier design.

(7714)

OIL CONTAINMENT SYSTEM DEVELOPMENT-WIND SET-UP OF OIL.

(b) United States Coast Guard.

(c) Dr. Robert M. Sorensen.

(d) Theoretical and experimental; basic research; M.S. thesis.

(e) The purpose is to determine, by theoretical and experimental considerations, the set-up of floating oil retained by a barrier and subjected to a given wind velocity. A theoretical prediction of oil wedge thickness as a function of wind velocity and oil properties has been developed and is being tested in the two-dimensional wind-wave tank.

(7715)

SCOUR AROUND A CIRCULAR CYLINDER DUE TO WAVE MOTION.

(c) Dr. Robert M. Sorensen, Donald R. Wells.

(d) Experimental; basic research; master's thesis.

(e) A vertical circular cylinder to simulate a pile was installed in the two-dimensional wave tank along with a built up section containing a horizontal bed of fine sand. This was subjected to monochromatic waves of differing characteristics and conditions for incipient motion were observed for each of three sands. Also, the magnitude and pattern of ultimate scour and the time interval required to reach this state were measured for six different conditions of wave steepness and relative depth.

These results were related to influential parameters that combine wave, pile and sediment characteristics and were developed by dimensional analysis with consideration of the literature pertaining to past work on the movement of sediment by oscillatory flow. Conclusions regarding the critical flow velocity for incipient motion, the effect of the above parameters on incipient motion and ultimate scour depth, the time required for maximum scour, the significance of eddies generated by the pile, and the catalytic action of the pile in causing the initiation of scour are presented.

The above conclusions are also generally discussed in light of the difficulties involved in extending the results to prototype conditions.

(f) Completed.

(h) "Scour Around a Circular Pile Due to Oscillatory

(7716)

EFFECT OF FLUID VISCOSITY OF NON-NEWTONIAN FLUIDS ON
CAVITATION CHARACTERISTICS OF A DREDGE PUMP.

- (b) National Science Foundation Sea Grant Program.
- (d) Experimental; applied research; M.S. thesis.
- (e) Coastal water shell dredging is among the top five manufacturing services in Texas and is crucial to the state's economy. Shell and sand dredging are also important to the economy of other Gulf states and also to the whole Nation. The heart of any modern dredge is the centrifugal dredge pump and in the prior research conducted by the proposed principal investigator, it was discovered that dredge pumps are generally inefficient and that careful design may increase their performance considerably. On a project for the Army Engineers, a re-design of the pump to handle silt-clay-water mixtures increased its efficiency from 60 to 83%. With the modern trend of using higher speed electric motors, the cavitation problem in dredge pumps is quite serious. Major contribution is expected from the proposed project which will considerably decrease the cost of dredged sand and shell and which will increase the dredging depth. The re-circulating dredge pump facility has been constructed and tests will be conducted with clear water as well as with sand-water and shell-water dredging mixtures. The effect of pump geometry and materials pumped on pump characteristics and cavitation characteristics will be determined.

(7717)

DIGITAL COMPUTER MODEL OF BASE FLOW OF THE BRAZOS
RIVER.

- (b) Texas Water Rights Commission.
- (d) Theoretical; applied research; Ph.D. dissertation.
- (e) The object of the project is to prepare a computer model which estimates discharge at various points along the Brazos River during periods of base flow. Base flow is to be defined as all variables affecting flow in the river except storm runoff. The variables include reservoir operation, evapotranspiration, bank storage, seepage from shallow ground-water formations, infiltration through the streambed, tributary inflows, and abstractions for municipal, industrial, and irrigation uses and their return flows. Other variables may be present in any particular stream but would possibly require a detailed field search of the area such as nearby irrigation wells which draw water from the stream through connecting aquifers. The model is to be designed such that minimum probable flows may be predicted for downstream points for river management purposes. The basic differential equations of unsteady flow developed by De Saint-Venant and the storage equation are being considered.

(7718)

EFFECT OF SURFACE ROUGHNESS ON WAVE FORCES ON A
CYLINDRICAL PILE.

- (b) National Science Foundation Sea Grant Program.
- (c) Dr. Robert M. Sorensen.
- (d) Experimental; basic research; dissertation.
- (e) An accurate determination of wave forces is necessary for the safe and economical design of piles located in the coastal zone and offshore. Drag, inertial and lateral wave forces generally

will vary as the surface roughness of a pile changes due to growth of marine organisms, natural roughness of the pile, etc. Studies have indicated that steady supercritical flow drag forces can double with an increase in surface roughness over the range of roughnesses found in the ocean. Thus, unsteady drag forces as well as inertial (due to variations in the flow pattern and eddy zone size and shape) and lateral forces can be expected to show a significant increase in magnitude and perhaps fluctuations in frequency as increases occur in surface roughness. At present, insufficient information is available on this subject.

A calibrated circular cylindrical pile designed to provide continuous records of wave force and moment on an amplifier-recorder has been constructed and installed in the two-dimensional wave tank. With the pile surface smooth and then having various degrees of roughness (obtained by gluing sand to the pile surface) force and moment measurements will be made for a range of wave conditions.

Because of short-comings in the standard Morison approach which involves the determination of drag and mass coefficients, and the inability of wave theory to adequately define particle velocities and accelerations needed in the Morison approach, other methods will also be used to analyze the wave and force data in order to investigate the effects of surface roughness. Some authors have recommended that the Morison approach be discarded in favor of an analysis based upon the use of dimensionless parameters including the maximum force, wave height and period, water depth, pile diameter and fluid properties. This approach will be considered including the additional parameter of dimensionless roughness (i.e., surface roughness divided by pile diameter). Also, the force data will be related to Iverson's modulus (same as Keulegan and Carpenter's parameter) which attempts to combine drag and inertia effects of surface roughness.

- (h) "Effects of Surface Roughness on Waves Forces on Circular Cylindrical Piles," R. M. Sorensen and W. J. Burton, Proc. Civil Engrg. in the Ocean II Conf., Miami, Dec. 1969.

(7719)

CHARACTERISTICS OF WAVES BROKEN BY A LONGSHORE BAR.

- (c) Dr. Robert M. Sorensen, Clark E. McNair, Jr.
- (d) Experimental; basic research; master's thesis.
- (e) A two-dimensional model of a submerged offshore bar was installed in the wave tank and monochromatic waves of various heights and lengths were generated at this bar. Wave surface time-histories, for those waves that broke over the bar, were measured before and after the bar and spectral analyses of these measurements were performed. The heights of the reformed waves are shown to be a function of the deepwater steepness of the incident waves as well as the ratio of wave length to depth of submergence of the bar. The predominant periods of the reformed waves are found to be the same as for the incident waves but the presence of energy at higher frequency waves is suggested. Requirements for wave breaking are discussed as well as the nature of wave reflection from the bar.

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Professor Richard A. Geyer, Department Head.

(4866)

MODIFICATION OF TWO-DIMENSIONAL LONG WAVES OVER VARIABLE BOTTOM TOPOGRAPHY.

- (b) Coastal Engineering Research Center.
- (c) Prof. R. O. Reid.
- (d) Theoretical applied research.
- (e) The objective is to investigate the modification of free gravity waves in variable depth, including reflection and transmission, etc., with particular attention being given to the interaction of tsunamis with islands. The analysis employs numerical methods.
- (g) A numerical program for evaluation of the water level response at an island to a general plane wave input is employed to estimate the spectral transfer function at various points on the island.
- (h) "The Detection of a Multiple Tsunami Phenomenon," T. C. Royer and R. O. Reid, Texas A & M Research Foundation Project 471-A Tech. Rept. No. 69-12T, 52 pages, Sept. 1969.
"An Inverse Tsunami Problem," C. E. Knowles and R. O. Reid, to be published in Proc. Intl. Symp. on Tsunamis and Tsunami Research, Honolulu, Hawaii, Oct. 1969.

(7720)

NUMERICAL STUDIES OF THE DISPERSAL OF A DENSE EFFLUENT FROM A DESALINATION PLANT.

- (b) Dow Chemical Company.
- (c) Prof. R. O. Reid.
- (d) Applied research.
- (e) The objective is to determine the concentration along the axis of a plume of dense effluent which is discharged at general angle of elevation into a moving stream and also to find the configuration of the plume axis and its boundaries.
- (g) Studies to date have been restricted to the case of vertical and inclined jets in a still fluid. The results correlate well with experiments carried out at Dow Chemical Company.
- (h) "Disposal of Effluents from Desalination Plant," M. A. Zeitoun, W. F. McIlhenny, and R. O. Reid, Chem. Engrg. Prog., Symposium Series, Vol. 65, No. 97, pages 156-166, 1969.

TEXAS A&M UNIVERSITY, Water Resources Institute, College Station, Texas 77843. Dr. J. R. Runkles, Institute Director.

(7721)

A HYDROMETEOROLOGICAL STUDY RELATED TO THE DISTRIBUTION OF PRECIPITATION AND RUNOFF OVER SMALL DRAINAGE BASINS-- URBAN VERSUS RURAL AREAS.

- (c) Dr. Robert A. Clark, Dept. of Meteorology.
- (d) Field and laboratory investigation; applied research.
- (e) Rainfall and runoff data from both an urban rural basin located 3 mi. apart are being studied. The urban basin located in Bryan, Texas, has a drainage area of 1.39 sq. mi.--24 percent of the area is impervious. The rural basin drains 1.98 sq. mi. Comparisons are being made between the two basins to determine the effects of urbanization and runoff. Other parameters related to runoff are being studied also.
- (g) Studies to date have shown the unit hydrograph peak in the urban basin to be approximately twice that for the rural basin. As expected, the time-to-peak was less than one-half that in the rural

area. Although both basins are sensitive to antecedent moisture, the rural basin appears to be affected more than the urban basin. Infiltration rates and rainfall intensity also appear to be highly correlated in both basins.

- (h) "On the Variability of Streamflow-Urban versus Rural Areas," Robert G. Feddes, M.S. thesis, Texas A&M Univ., Jan. 1970.
"Investigation of the Linear Convolution Model to Describe the Rainfall-Runoff Phenomenon of Drainage Basins," Frederick A. Schmer, Ph.D. dissertation, Texas A&M Univ., Jan. 1970.
"A Study of the Observed Area Distribution of Rainfall as a Function of the Density of Rain Gages," Fernando Alvarez, M.S. thesis, Texas A&M Univ., Aug. 1969.
"Application of the Linear Convolution Model in Describing the Rainfall-Runoff Relationship of an Urban Drainage Basin," Fred A. Schmer, Robert A. Clark, Edward A. Hiler, Robert G. Feddes, presented at Fall Natl. Meeting, Amer. Geophys. Union, San Francisco, Calif., Dec. 1969.

UNIVERSITY OF TEXAS AT AUSTIN, College of Engineering, Department of Civil Engineering, Austin, Texas 78712.
Dr. Walter L. Moore.

(2161)

CHARACTERISTICS OF A HYDRAULIC JUMP AT AN ABRUPT CHANGE IN BOTTOM ELEVATION.

- (b) Univ. of Texas Research Institute and Bureau of Engineering Research.
- (c) Dr. Carl W. Morgan, Assoc. Prof.
- (d) Experimental.
- (e) Experimental determinations were made of the flow characteristics at two-dimensional channel drops and rises. The velocity distribution and surface profile were determined throughout the length of the jump for various relative changes in bottom elevation. The longitudinal location of the jump in relation to the change in bottom elevation was varied over a broad range in contrast with previous related investigations in which relative location of the jump was held constant.

(2162)

HYDROLOGIC STUDIES, WALLER CREEK WATERSHED.

- (b) Cooperative with U.S. Geological Survey.
- (d) Field investigation; applied research.
- (e) Measurements of rainfall and runoff for a 4-square mile and a 2-square mile portion of the Waller Creek watershed are being made to provide basic information for estimating runoff from small urban watersheds in the Southwest area. Two stream flow stations and a rain gage net are in operation. Studies of the correlation between runoff, rainfall, and the characteristics of the drainage basin are being made by various proposed methods to serve as a base comparison with the data as it is collected.
- (g) Data has been collected since 1956 by the U.S.G.S. and for later years is available in special reports listed below. Data has been used in a number of hydrologic studies and its use will continue.
- (h) "Compilation of Hydrologic Data, Waller and Wilbarger Creeks, Colorado River Basins, 1965," Geological Survey - Water Resources Division, Austin, Texas.

(4234)

EVAPORATION REDUCTION BY CONTROL OF ADVECTED ENERGY.

- (b) Lower Colorado River Authority of Texas.

- (d) A Master's thesis involving theoretical and field investigation.
- (f) Discontinued.
- (h) "Selective Withdrawal as a Means of Reducing Evaporation from Reservoirs," Clovis S. Vaughn, Hydraulic Engrg. Lab., Tech. Rept. No. HYD 02-6301, Univ. of Texas, Austin, Texas, 1963.
- (4235)
TWO-PHASE FLOW IN CONDUITS.
- (d) Experimental; Master's thesis.
- (e) It is apparent that for a two-phase flow system with a liquid and gas, many different types of flow are possible. This investigation explored the use of sound measurements to detect the type of flow present, in a metal pipe. Various types of flow were established in a thin-walled aluminum pipe, 1.66 I.D., with a transparent plastic section at each end. Records of the sound pattern were made with different pick-ups and correlated with the visual observation of the flow type. Magnetic tape records of the sound were also made.
- (g) Study of the recorded sound patterns revealed some identifiable characteristics related to the type of two-phase flow in the line. Additional work is needed to refine techniques and try other sound pick-up and recording methods.
- (h) "Sonic Signatures of Multiphase Flow," Robert G. Haindman, Master's thesis, 1962, Dept. of Civil Engrg., Univ. of Texas at Austin.
- (4716)
DRAG FORCES IN VELOCITY GRADIENT FIELDS.
- (b) Naval Ship Research and Development Ctr.
- (c) Dr. Frank D. Masch and Dr. Walter L. Moore.
- (d) Theoretical and experimental; basic research.
- (e) The investigation is being conducted to determine the effect of a velocity gradient on the local and conventional drag coefficients for cylinders of varying L/D ratio and at different Reynolds Numbers. The study will be extended to other shapes.
- (f) Completed.
- (g) Studies have demonstrated that the velocity gradient along a cylinder affects the drag coefficient. The local drag coefficient decreases along the cylinder in the direction toward the end of the cylinder where the velocity is high. The reduction in drag coefficient is related to a dimensionless measure of the velocity gradient along the cylinder. The angle at which separation occurred was found to increase near the bottom of the cylinder where the free stream velocity is low.
- (h) "Influence of Secondary Flow on Drag Force," Charles Dalton and Frank D. Masch, J. Engrg. Mech. Div., Proc. Amer. Soc. Civil Engrs., Vol. 94, No. EM5, Oct. 1968, pp. 1249-1257.
- (4990)
WAVE CHARACTERISTICS IN SHOALING WATER.
- (c) Dr. Frank D. Masch.
- (d) Theoretical; basic and applied research; Master's thesis.
- (e) This study is to develop a workable method for computing water wave characteristics in shoaling water using cnoidal wave theory. The method involves evaluating the power transmission for a wave train in shallow water from cnoidal theory and using the concept of constant power between orthogonal on a refraction diagram. The study has been expanded to include computation of velocity, acceleration and pressure fields.
- (g) Integrals of the cnoidal functions have been evaluated in terms of elliptic integrals and computer programs have been developed to solve the resulting equations.
- (h) "Cnoidal Waves in Shallow Water," Frank D. Masch, Chapter I, Proc. Ninth Conf. on Coastal Engrg., ASCE, Lisbon, Portugal, 1964.
- "Velocity and Acceleration Fields," C. Y. Lee, M.S. thesis, The Univ. of Texas, Austin, May 1966.
- (5455)
HYDROLOGY OF SMALL URBAN WATERSHEDS.
- (b) Bureau of Engineering Research, Texas Water Commission.
- (c) Dr. Carl W. Morgan, and Dr. Frank D. Masch.
- (d) Field investigation, basic research.
- (e) Data from selected watersheds have been collected. These are being studied to evaluate the effects of urbanization on the hydrologic characteristics of the watersheds.
- (g) For the Waller Creek Watersheds, Austin, Texas, preliminary results indicate that because of approximately twice as high percent of impervious cover in the lower part it produced yields per unit area approaching twice that of the upper area.
- (h) "A Study of Some Effects of Urbanization on Storm Runoff from a Small Watershed," W. A. Espey, Jr., C. W. Morgan and F. D. Masch, Hydraulic Engrg. Lab. Tech. Rept. No. HYD 07-6501, The Univ. of Texas, July 1965.
- (5456)
MATHEMATICAL MODELS FOR RELATING RUNOFF TO RAINFALL.
- (b) Office of Water Resources Research.
- (d) Master's and Doctoral research based on computer analysis and field data.
- (e) Using the Stanford Watershed Model as a starting point a revised general procedure for a numerical simulation of watershed hydrology was developed with an effort to provide more realistic simulation of infiltration and soil moisture movement. Also work was done on using the Stanford Watershed model to investigate its use as a means for determining the effect of watershed changes on the streamflow.
- (g) The translation of the Stanford Watershed was used successfully for a number of purposes and the revised simulation procedure has been completed and a few limited applications made. The results appear promising.
- (h) "Numerical Simulation of a Watershed as a Means to Evaluate Some Effects of Floodwater Retarding Structures on Runoff," Erdal Coskun, and Walter L. Moore, Hydraulic Engrg. Lab., Rept. No. HYD 14-6901, Dept. of Civil Engrg., 1969, Center for Research in Water Resources No. 45. The Univ. of Texas at Austin.
- "Numerical Simulation of Watershed Hydrology II," B. C. Claborn and Walter L. Moore, 1970, Hydraulic Engrg. Lab. Rept., No. 14-7002, Center for Research in Water Resources No. 54.
- (5457)
A NEW TYPE ENERGY DISSIPATOR FOR CULVERT OUTLETS.
- (b) Texas Highway Dept. and U. S. Bureau of Public Roads.
- (d) Experimental and theoretical thesis work.
- (e) A study is being made of a culvert energy dissipator based on the use of a sector of a circular hydraulic jump. Apparent advantages of the device are the stability of the jump over a range of discharge and tailwater conditions and the opportunity to spread the culvert discharge back to the original stream width. Problems of practical geometry have been explored and initial designs

- developed for a structure that performs well for a considerable range of tailwater conditions. The structure is adaptable for use either at the outlet of a box culvert or a circular pipe culvert.
- (h) "Radial Flow Energy Dissipator for Culvert Outlets," Raymundo Aguirre and Walter L. Moore, Rept. No. 92-1, Center for Highway Research, Univ. of Texas at Austin, Nov. 1967, HYD 11-6701. "Culvert Outlet Energy Dissipator Incorporating Radial Flow and a Transverse Sill," Robert R. Wear and Walter L. Moore, Research Rept. 92-3, Center for Highway Research, Univ. of Texas at Austin, HYD 11-6801, Jan. 1968. "Adaptation of Radial Flow Energy Dissipator for Use With Circular or Box Culverts," Walter L. Moore and Khosrow Meshgin, Research Rept. 92-5, Center for Highway Research, Univ. of Texas at Austin, Dec. 1969.
- (5458)
SEDIMENTATION IN GALVESTON-TRINITY BAYS.
(b) Texas Parks and Wildlife Commission.
(c) Dr. Frank D. Masch.
(d) Experimental, field; applied research.
(e) Field investigation to determine the currents, sources of sediment, and sediment movement in Galveston and Trinity Bays, and to determine the effect they may have on the dredging of mudshell, oysters and oyster production.
(h) "General Considerations Prerequisite to Further Galveston Bay Shell Removal," Floyd R. Hill and Frank D. Masch, Hydraulic Engrg. Tech. Rept. No. HYD 15-6901, Univ. of Texas, July 1969, 50 pp.
- (5459)
FINITE-AMPLITUDE GRAVITY WAVES.
(c) Dr. L. R. Mack, Dept. of Engrg. Mechanics.
(d) Theoretical; basic research.
(e) Our previously published treatment breaks down for very small values of the depth-to-wave-length ratio; this breakdown is now recognized as a singular perturbation problem. Appropriate stretching of the vertical coordinate and the depth parameter facilitates use of the method of matched asymptotic expansions to obtain a valid solution for small depth. Velocity, surface configuration, and frequency of oscillation are being obtained.
- (5460)
WIND WAVE OVERTOPPING OF SHORELINE STRUCTURES.
(b) Bureau of Engrg. Research, Univ. of Texas.
(c) Dr. Frank D. Masch.
(d) Experimental; thesis.
(e) This study is designed to compare overtopping from wind waves with that predicted from criteria based on uniform wave trains. Overtopping is being measured under varying wind and wave conditions. Particular study is being given to beach geometry immediately in the front of the structure and its effect on overtopping rates.
(g) Results obtained to date show that the greater the depth of water at the wall, the greater the overtopping rates. The offshore beach profiles appear to have little or no effect on overtopping from wind generated waves.
- (5461)
ANALYSIS OF UNIT HYDROGRAPHS FOR SMALL WATERSHEDS.
(c) Dr. Carl W. Morgan.
(d) Field investigation; thesis.
(e) Characteristic, two-hour unit hydrographs were determined for each of three selected watersheds. The derived dimensionless hydrograph shapes were compared with two widely used empirical hydrographs. Techniques were studied for using the S-curve hydrograph as an aid in estimating the correct duration of rainfall excess by selecting that duration which caused the least fluctuation in the S-curve.
- (f) Completed.
(g) The dimensionless 2-hour unit hydrographs developed in this study indicate that the falling limbs of the Commons and Mockus hydrograph shapes may need revision in order to be applied to watersheds of less than 100 square miles in area. However, these differences are only minor, suggesting that an average dimensionless graph and reliable estimates of only two parameters, period of rise and peak discharge, may be sufficient to define the shape of the unit hydrograph. Results indicate the S-curve can be used to estimate by trial and error the rainfall excess duration if rainfall data is not available.
- (h) "Analysis of Unit Hydrographs for Small Watersheds in Texas," Wilbur L. Meier, M.S. thesis, Univ. of Texas at Austin, Aug. 1964.
- (5953)
MIXING AND DISPERSION OF CONTAMINANTS IN RESERVOIRS.
(b) Federal Water Pollution Control Admin.
(c) Dr. Frank D. Masch.
(d) Basic and applied research; field investigation.
(e) This investigation has been undertaken to study the mixing and dispersion of contaminants in inland fresh waters. The study includes an investigation of the effects of currents, turbulent wave action, and periodic overturning on the disposition of waste materials discharged into reservoirs and lakes. The stability effects of temperature and density gradients within the receiving waters are also being determined. Mixing processes in both deep and shallow water reservoirs are being studied in the field.
(h) "Relationship Between the Physical and Biological Environments--Physical Exchange," Joe R. Wilson and Frank D. Masch, Advances in Water Quality Improvement, Water Resources Symp., No. 1, Univ. of Texas Press, 1968, pp. 103-110. "Evaluation of Micro-Models for Near Surface Dispersion in Reservoirs," Thomas G. Gebhard and Frank D. Masch, Hydraulic Engrg. Tech. Rept. No. HYD 10-6902, Univ. of Texas, July 1969, 141 pp.
- (5955)
PERFORMANCE OF CIRCULAR CULVERTS ON STEEP GRADES.
(b) Texas Highway Department.
(c) Dr. Frank D. Masch.
(d) Experimental and theoretical research.
(e) This study is concerned with the behavior of the hydraulic jump in circular broken-back culverts. Of particular concern are the conditions under which a jump will form in the culvert. The study is also concerned with methods to insure that the jump forms in the culvert.
(h) "End Sills and the Forced Hydraulic Jump in Circular Culverts Operating at Low Discharge Factors," Robert J. Brandes, Manam V. P. Rao, and Frank D. Masch, Research Rept. 92-4, Project 3-5-66-92, Cooperative Highway Research Program with Texas Highway Dept. and U.S. Dept. of Transportation, Bureau of Public Roads, Center for Highway Research, Univ. of Texas at Austin, June 1969, 90 pp.
- (6180)
TEMPERATURE FIELDS IN STRATIFIED RESERVOIRS.
(b) Texas Electric Service Company.
(d) Applied research; laboratory investigation.
(e) The temperature and velocity field in a stratified

reservoir has been studied by use of a generalized laboratory model, 8 ft. long, 1 ft. wide, and 2 ft. deep. In the laboratory model factors may be varied; such as the temperature and amount of heated inflow, location of inflow, location of outflow, heat input through surface radiation, and wind shear at the surface. The temperature field and its change with time was measured by 100 thermistors located at selected points throughout the model. The velocity patterns were measured by observing and photographing the motion of dye streaks. The results indicate a thermocline development generally as expected but a reversing flow direction in alternate layers which appears to be related to multiple jets observed by others in experiments with continuously stratified flow and in axially directed flow in a rotating fluid. A report is nearing completion on the work to date.

(6182)
DISPERSION IN SHALLOW ESTUARIES OF IRREGULAR SHAPE.

- (b) Office of Water Resources Research.
- (c) Dr. Frank D. Masch.
- (d) Analytical and experimental research.
- (e) This research involves the development and verification of a numerical model to evaluate transport characteristics in shallow vertically mixed estuaries of arbitrary shape. The model is designed to assist in developing water quality requirements and assimilative capabilities of estuaries typical of those found along the Gulf Coast of the United States. The study includes adaptation of an existing numerical model of the two-dimensional, time-dependent convective dispersion equation and the evaluation of dispersion coefficients from graphical and analytical considerations of the scale of turbulence and circulation in the estuary.
- (h) "A Numerical Model for the Simulation of Tidal Hydrodynamics in Shallow Irregular Estuaries," Frank D. Masch, N. J. Shankar, M. Jeffrey, R. J. Brandes, and W. A. White, Hydraulic Engrg. Tech. Rept. No. HYD 12-6901, Univ. of Texas, Feb. 1969, 123 pp.

(6183)
RELATION OF PASSES ON PHYSICAL EXCHANGE OF SALINITY IN ESTUARIES.

- (b) Office of Water Resources Research and Texas Water Development Board.
- (c) Dr. Frank D. Masch.
- (d) Experimental and theoretical research.
- (e) Most of the estuaries along the Texas Gulf Coast are separated from the Gulf of Mexico by a long thin chain of offshore or barrier islands. The exchange between gulf and bay waters takes place through a few natural and artificial passes through the barrier islands. It is the principle objective of this proposed project to determine whether the physical exchange of waters between the bays and gulf can be increased by either dredging new passes, or by enlarging existing passes through the barrier islands. In particular, the effects of modifications or additions of passes on the volume of physical exchange, the degree of mixing, and on salinity gradients is to be determined.
- (h) "Mathematical Simulation of Two-Dimensional Horizontal Convective-Dispersion in Well-Mixed Estuaries," N. J. Shankar and Frank D. Masch, Proc. Thirteenth Congr. Intl. Assoc. Hydraulic Res., Kyoto, Japan, 1969, pp. 293-301.

(6184)

NATURAL CONVECTION WITHIN ENCLOSED SPACES.

- (c) Dr. L. R. Mack, Dept. of Engrg. Mechanics.
- (d) Experimental and theoretical; basic research.
- (e) Velocity, temperature, and pressure distribution, heat transfer, and stability of flow. Current work on pressure distribution and stability characteristics of fluid between horizontal concentric cylinders, each maintained at a different temperature.
- (h) "Natural Convection Between Concentric Spheres at Low Rayleigh Numbers," L. R. Mack and H. C. Hardee, Intl. J. Heat and Mass Transfer, Vol. 11, pp. 387-396, March 1968.
- "Natural Convection Between Horizontal Concentric Cylinders for Low Rayleigh Numbers," L. R. Mack and E. H. Bishop, Quart. J. of Mech. and Appl. Math., Vol. 21, pp. 223-241, May 1968.

(7722)

LAMINAR FLOW BETWEEN ROTATING CONCENTRIC SPHERES WITH HEAT TRANSFER.

- (c) Dr. L. R. Mack, Dept. of Engrg. Mechanics.
- (d) Theoretical; thesis.
- (e) Velocity and temperature fields of viscous fluid enclosed between two rotating concentric spheres of different temperatures. Higher-order details of the secondary flow and its influence on heat transfer for various combinations of relative importance of the two driving mechanisms (moving surface, buoyancy).

(7723)

EFFECTS OF UPSTREAM FLOOD CONTROL MEASURES ON WATERSHED YIELD.

- (b) U. S. Geological Survey.
- (c) Dr. Frank D. Masch.
- (d) Analytical and field.
- (e) A mathematical model for monthly consumption by reservoirs was developed. The model consists of a linear multiple regression equation relating monthly consumption to combinations of variables considered to be representative of the physical processes involved in evaporation from the free water surface and wetted peripheral soil, transpiration, and seepage away from the pools. The prediction equations have standard errors of estimate ranging from 11 percent to 16 percent. A computer program which models the hydrologic response of a system of upstream floodwater-retarding reservoirs was developed also utilizing the mathematical model for monthly consumption. Necessary parameters may be determined from soil maps, and reservoir design. Climatic variables are computed from existing first order climatological data stations. The program is suggested for use in water yield studies to adjust historical streamflow records for the effects of upstream flood control programs.
- An annual inflow-outflow relationship was developed based on data collected in all areas. This relation may be used as a reasonable first approximation of the depletion of annual runoff from the controlled area of a watershed.
- (h) "Methods for Evaluating the Effects of Upstream Flood Control Measures on Watershed Yield," Stanley P. Sauer and Frank D. Masch, Hydraulic Engrg. Tech. Report No. HYD 13-6901, Univ. of Texas, May 1969, 104 pp.
- "Effects of Small Structures on Water Yield in Texas," S. P. Sauer and Frank D. Masch, Effects of Watershed Changes on Streamflow, Water Resources Symposium, No. 2, Univ. of Texas Press, 1969, pp. 118-135.

TRW SYSTEMS GROUP, Applied Mechanics Laboratory, One
Space Park, Redondo Beach, California 90278. Dr.
Pravin G. Bhuta, Laboratory Manager.

(7724)

VISCOUS DAMPING IN FLUID DAMPERS FOR SPACECRAFT.

(b) Goddard Space Flight Center, NASA.

(c) Drs. H. F. Korman and L. R. Koval.

(d) Theoretical, applied research.

(e) The purpose of this study was to calculate the amount of viscous dissipation of oscillatory mechanical energy in various damper configurations and to determine the values of the parameters which produced an optimal amount of dissipation, consistent with other design constraints on the spacecraft. These results have been used to determine the best methods for damping out unwanted oscillations in component parts, such as gravity-gradient stabilization booms and Radio Astronomy Explorer (RAE) antennae.

(f) Completed.

(g) Three damper configurations were analyzed: a torus of circular cross-section, a fluid filled sphere, and a spherical annulus with a motionless inner sphere. The energy dissipated by the viscous fluid was calculated for sinusoidal oscillations of the torus or outer sphere by solving the Navier-Stokes equations in the appropriate fluid filled regions. An optimal value of the Reynolds number parameter was found which produced a maximum amount of dissipation for the torus and fluid filled sphere. Although the analysis of the spherical annulus did not yield this effect because of the assumption of a motionless inner sphere, the inertial coupling of the sphere to the fluid motion will result in an optimum Reynolds number. A comparison of the results for the different configurations shows that the torus and the spherical annulus provide the best damping.

(h) "Final Report for Study on Fluid Dampers for Booms," Advanced Technology Dept., Rept. No. 09871.00-6011-T0-00, TRW Systems Group, July 1968. "Final Report for Study of a Spherical Annular Boom Damper," Advanced Tech. Dept. Rept. No. 12726-6011-R0-00, TRW Systems Group, July 1969. "Energy Dissipation in an Oscillating Sphere Filled with a Viscous Fluid," R. Arahamian, R. L. Johnson and L. R. Koval, AIAA J., Vol. 7, No. 9, pp. 1793-1796, Sept. 1969. "Energy Dissipation in an Oscillating Spherical Annulus Filled with a Viscous Fluid," H. F. Korman and L. R. Koval, to be submitted to AIAA.

(7725)

ZERO GRAVITY LIQUID-GAS SEPARATOR; ENGINEERING EVALUATION MODEL.

(b) NASA Manned Spacecraft Center, Houston, Texas.

(c) D. J. Graham.

(d) Experimental; concept evaluation.

(e) A breadboard device using the phenomenon of surface tension, acting across fine screen pores, to separate liquid from a liquid-gas sample was designed and constructed. The unit was tested in a minus one-g configuration and found to meet (and in some cases exceed) performance requirements established by NASA/MSC.

(f) Completed.

(g) The surface tension device was found to extract essentially 100% of the liquid in the initial liquid-gas sample and expel this liquid to a separate collection tank. Tests in a zero or low-g environment were not part of this program

but it is anticipated that the lower energy configuration in low-g of wall-bound liquid will result in high liquid extraction efficiencies.

(h) "Zero Gravity Liquid-Gas Separator-Engineering Evaluation Model," D. J. Graham, Rept. No. 13288-6001-R0-00, TRW Systems Group.

UTAH STATE UNIVERSITY, College of Engineering, Utah
Water Research Laboratory, Logan, Utah 84321. Jay M.
Bagley, Laboratory Director.

The following projects are reported as titles only. Details are to be found in the "Water Resources Research Catalog":

(042W)

STATE WATER PLAN INVESTIGATIONS.

(044W)

DEVELOPMENT AND EVALUATION OF IMPROVED TECHNIQUES TO MEASURE WATER-CONTENT OF SNOW.

(126W)

SEQUENTIAL WATER USE WITHIN A HYDROLOGIC COMPLEX.

(See also No. 5478 in 1968 issue.)

(127W)

OPTIMIZING CONJUNCTIVE USE OF SURFACE AND GROUNDWATER.

(See also No. 5749 in 1968 issue.)

(128W)

SORPTION KINETICS IN FLOW THROUGH GRANULAR PARTICLES.

(129W)

OPEN CHANNEL ROUGHNESS CHARACTERISTICS.

(130W)

THE SIMULATION OF HYDROLOGIC EVENTS IN ARID REGIONS.

(131W)

SNOW COVER COMPACTION AND SOIL MOISTURE.

(132W)

ANALYSIS OF DESALTING PLANTS AS A SOURCE OF SUPPLEMENTAL SAFE YIELD.

(133W)

COMPUTER SIMULATION OF URBAN HYDROLOGIC SYSTEMS.

(134W)

ANALYSIS OF SMALL WATER MANAGEMENT STRUCTURES.

(135W)

WATER QUALITY TELEMETRY.

(See also No. 6528 in 1968 issue.)

(136W)

LABORATORY CATCHMENT INVESTIGATIONS RELATING TO HYDROLOGIC SYSTEMS ANALYSIS.

(137W)

APPLICATION OF OPERATIONS RESEARCH TECHNIQUES FOR ALLOCATION OF COLORADO RIVER WATERS IN UTAH.

(138W)

ELECTRONIC ANALOG SIMULATION OF THE SALINITY FLOW SYSTEM WITHIN THE UPPER COLORADO RIVER BASIN.

(See also No. 6521 in 1968 issue.)

(139W)

APPLICATION OF ELECTRONIC ANALOG COMPUTER TO THE SIMULATION OF THE TOTAL HYDROLOGIC-ECONOMIC FLOW SYSTEM.

(See also No. 6520 in 1968 issue.)

(140W)
THE DEVELOPMENT OF SIMULATION MODEL FOR THE BEAR RIVER BASIN.

(141W)
A STUDY OF THE INTEGRATION OF THE WATER RESOURCES OF THE BEAR, WEBER, AND JORDAN RIVERS IN NORTHERN UTAH.
(See also No. 6518 in 1968 issue.)

(142W)
APPLICATIONS OF ANALOG COMPUTER SIMULATION TECHNIQUES FOR RUNOFF PREDICTIONS WITHIN THE REYNOLDS CREEK WATERSHED.

(See also No. 6517 in 1968 issue.)

The following projects will be in the next issue of the Water Resources Research Catalog:

(144W)
A STUDY OF WATER INSTITUTIONS IN UTAH AND THEIR INFLUENCE ON THE PLANNING, DEVELOPING, AND MANAGING OF WATER RESOURCES.

(145W)
THE DETECTION OF MAGNETIC FIELDS CAUSED BY GROUND-WATER.

(146W)
EVALUATION OF THE FLOOD RISK FACTOR IN THE DESIGN OF STORM DRAINAGE SYSTEMS FOR URBAN AREAS.

(147W)
REGIONAL ANALYSIS OF RUNOFF CHARACTERISTICS OF SMALL URBAN WATERSHEDS.

(3183)
DYNAMICS OF FLOW IN STEEP, ROUGH, OPEN CHANNELS.

- (b) National Science Foundation.
(c) Dr. Dean F. Peterson, Dean of Engrg.
(d) Experimental, theoretical, field investigation; basic research for doctoral theses.
(e) A basic study of relationships involved in flow in steep, rough channels where the roughness is relatively an appreciable part of the depth, and where channels are sufficiently steep or steeper than a slope such that super-critical flow can occur in connection with contractions caused by the roughness. The work is basic; however, it will have application to steep mountain streams and to hydraulic structures.
The objective of the work is to relate descriptive parameters describing the size and configuration of the bed roughness to slope, depth and discharge of channels of this class. Flume studies began using simple bar and cube elements and have progressed through the use of beds formed by gluing natural gravel elements of various size, gradation and intensity to the bed. Nineteen field sites were installed in streams, principally in northern Utah in the Wasatch Mountains, but also in New Mexico and Colorado. Piezometric type stilling wells have been installed at thirteen sites and discharge and depth measured. Bed element distribution and size have been studied at all sites. Collection of field data has been completed and analysis is continuing. The flume study was repeated using the same beds only in a mirrored effect to eliminate the free surface influence, with air as the fluid.
(f) Completed.
(g) In the flume studies, discharge and slope were varied and depth was measured for each of the ten beds. Two sizes of material with five different spacings for each size were used. Experimental results show a continuous change in

relative dominance of the factors of gross velocity variation and turbulent mixing as the kineticity and relative depth changes. Six flow zones defined by Froude number and relative depth were suggested. It was not practical to develop a single equation to describe a conductance coefficient, $C/g^{1/2}$, to cover all ranges of flow, but one equation for each zone is proposed. C is from Chezy's equation and is based on roughness spacing parameter, roughness height, and depth of flow. A measure for describing spacing was developed using the concepts gained from the flume studies to provide a model. Effects of relative roughness, gradation and slope were related to flow in the natural channels. By comparing the flume and air duct studies, the free surface effects, principally spills, were separated from the skin friction and form drag. In steep channels in the field, boulders are combined into combination roughness "steps" across the bed at relatively uniform spacing depending on slope and bed element size.

- (h) "The Dynamics of Flow in Steep, Rough Channels," Abbas Al Khafaji, Ph.D. thesis, Utah State Univ., 1961.

"Flume Study of Steep Flow with Large Graded Natural Roughness Elements," N. S. Kharrufa, Ph.D. thesis, Utah State Univ., 1962.

"Hydraulics of Large Bed Element Channels," Harl E. Judd and D. F. Peterson, Jr., Utah Water Research Lab., Utah State Univ., PRWG 17-6, 1969.

(5130)

FARM IRRIGATION STRUCTURES.

- (b) Office of Water Resources Research.
(c) Lloyd H. Austin, Research Engineer.
(d) Library research combined with design analysis.
(e) A compilation of the material pertaining to the design of small irrigation structures that would be found on a farm. Will also determine gaps in information which will require additional research.
(f) Completed.
(h) "Analysis of Small Water Management Structures in Irrigation Distribution Systems," Gaylord V. Skogoyboe, Wynn R. Walker, Brent B. Hacking, and Lloyd H. Austin, Utah Water Research Lab., Utah State Univ., PRWG 55-1, June 1969.

(5452)

HYDRODYNAMICS OF FREE SURFACE FLOW OVER HYDRAULIC STRUCTURES.

- (c) Dr. Gary Z. Watters, Assoc. Prof. of Civil Engrg., Utah State Univ.
(d) Theoretical and experimental; for Ph.D. dissertation.
(e) An approximation to real fluid flow over hydraulic structures is being attempted by using a rotational ideal fluid. It is hoped that separation zones can be adequately enough described by this approximation to yield meaningful pressures, velocities, discharge coefficients and free surface locations.

(5750)

ATMOSPHERIC WATER RESOURCES IN UTAH.

- (b) United States Bureau of Reclamation.
(c) Dr. George W. Reynolds, Principal Investigator for Meteorological Analysis; Professor Joel E. Fletcher, Principal Investigator for Water Management; Dr. C. Earl Israelsen, Principal Investigator for Field Support; and Dr. Jay M. Bagley, Director, Utah Water Research Laboratory, is Project Coordinator.
(d) Project is primarily experimental, heavily dependent upon field investigations and can be

- classified as both basic and applied research.
- (e) Cloud seeding is in progress along the Wasatch Front to determine the feasibility of increasing water supplies, delineating the areas affected by individual generators, and determining the unique characteristics of the snow producing storm systems. The investigation includes the installation and operation of a dense telemetering precipitation measurement network; meteorological and hydrologic support systems and studies; statistical evaluation.
- (h) "USU Remote Total Precipitation Telemetering Station," Duane G. Chadwick, Utah Water Research Lab., Utah State Univ., July 1968.
"Telemetry System Modifications and 1968-69 Operation," Duane G. Chadwick, Utah Water Research Lab., Utah State Univ., July 1969.
"A Phase-Lock Tracking Filter for Use in the Recovery of Low-Level Telemetry Data from Noise," Don L. Griffin, Utah Water Research Lab., Utah State Univ., June 1969.
"USU Telemetering Precipitation Gage Network," C. Earl Israelsen and Don L. Griffin, Utah Water Research Lab., Utah State Univ., June 1969.
"Background Ice Nuclei in a Quasi-Rural Intermountain Valley-- Cold Season," George W. Reynolds and William Slusser, Utah Water Research Lab., Utah State Univ., Feb. 1970. (Preprint).
- (6524)
INCIDENT MOTION OF LARGE ROUGHNESS ELEMENTS IN TURBULENT OPEN CHANNEL FLOW.
(b) National Science Foundation.
(c) Dr. Calvin G. Clyde, Asst. Director.
(d) Theoretical and experimental; basic research; Ph.D. dissertation.
(e) Suitable criteria were developed for the incipient motion of large roughness elements (hemispheres and spheres varying in diameter between 3 and 12 inches) in turbulent open channel flow under prototype conditions. The parameters utilized were time-dependent lift and drag forces, intensity of turbulence, edge velocity, velocity and gradients, flow depths, discharge, and energy gradient. The flow resistance of large roughness elements was measured in order to extend present flow resistance data to large elements and, also, to verify whether or not particular criteria developed from research on various smaller roughness elements by other investigators are applicable to the larger roughnesses. The interrelationships between time-dependent lift and drag forces, intensity of turbulence, probability of incipient motion, flow resistance, and other hydraulic parameters were studied.
(f) Completed.
(g) Beds of spheres (3-3/4 inch and 12-inch diameter) have been prepared and experiments run in the 6 ft. by 8 ft. by 500 ft. flume. Instrumentation has been developed to measure simultaneously the x, y and z components of total fluctuating force on one hemispherical roughness element.
(h) "Two-Dimensional Flow Resistance Over a Bed of Spherical Roughness Elements," Robert Pi-Chang Yu, M.S. thesis, Utah State Univ., 1969.
"Incipient Motion of Large Roughness Elements in Turbulent Open Channel Flow," Edmond D. H. Cheng, Ph.D. thesis, Utah State Univ., 1969.
"A Dynamometer for Measuring Force Components on Large Roughness Elements in Open Channel Flow," Calvin G. Clyde and Edmond D. H. Cheng, Preprint, Utah State Univ., 1969.
- (6525)
HYDRODYNAMIC FORCES IN NON-COHESIVE BED PARTICLES, INCLUDING SEEPAGE.
(b) National Science Foundation.
(c) Dr. Gary Z. Watters, Assoc. Prof., Civil Engrg. Dept.
(d) Experimental; for Ph.D. dissertation.
(e) Fine sand particles on the beds of alluvial streams are modeled in a recirculating flume. The fluid is oil and spheres 3.75 inches in diameter represent the sand particles. The effect of seepage on the forces exerted on the bed particles by the flowing fluid is measured by a strain-gage dynamometer. The object of the study is to determine whether or not seepage does influence the hydrodynamic forces and, if so, to what degree and under what conditions.
(f) Completed.
(h) "Effect of Effluent and Influent Seepage on the Hydrodynamic Forces Acting on Idealized Non-Cohesive Sediment Particles," Manam V. Panduranga Rao, Ph.D. dissertation, Utah State Univ., June 1969.
- (6526)
FEASIBILITY OF RATING CURRENT METERS IN A VELOCITY FIELD.
(b) U. S. Geological Survey.
(c) Dr. Calvin G. Clyde, Assistant Director.
(d) Experimental; applied research.
(e) The primary objective of this study is to investigate the feasibility of rating current meters by placing them in a submerged jet emanating from a contracting cone section. Model cones will be constructed based upon both published design criteria and theoretical analysis. The model cones will be evaluated for uniformity of the velocity field and the effects of placing a pygmy meter in the jet. The results of the model studies will form the basis for designing a prototype system, which will be evaluated using the standard current meters used by the U.S. Geological Survey.
(f) Completed.
(h) "Feasibility of Rating Current Meters in a Velocity Field," Rpt. No. PRWG 51-1, Utah Water Research Lab., Utah State Univ., Jan. 1968.
- (6527)
STEADY STATE PLANE SEEPAGE THROUGH NON-HOMOGENEOUS POROUS MEDIA AND AXIAL SYMMETRIC SEEPAGE.
(b) National Science Foundation.
(c) Roland W. Jeppson, Associate Professor.
(d) Theoretical applied research.
(e) The objectives of the proposed research are to obtain solutions to the following steady state, free surface seepage problems using appropriate transformations by the methods of finite differences: (1) two-dimensional plane seepage from channels of arbitrary geometry through non-homogeneous porous media to a drained layer at a specified finite depth; (2) axial symmetric seepage from ponds of arbitrary profiles through homogeneous isotropic or anisotropic porous media which may consist of layers of different permeabilities to a drained layer at a specified depth; (3) axial symmetric flow to a production well (and from a recharge well) which partially or fully penetrates a homogeneous isotropic or anisotropic aquifer.
(f) Completed.
(h) "Axisymmetric Seepage Through Homogeneous and Nonhomogeneous Porous Mediums," R. W. Jeppson, Water Resources Res., Vol. 4, No. 6, 1968, pp. 1277-1288.

"Solution to Axisymmetric Seepage from Ponds through Homogeneous and Nonhomogeneous Porous Media," Rept. No. WG 52-2, Utah Water Research Lab., Utah State Univ., May 1968.
 "Free-Surface Flow through Heterogeneous Porous Media," R. W. Jeppson, J. Hydr. Div., ASCE, Vol. 95, No. HYL, Proc. Paper 6364, Jan. 1969, pp. 363-381.

(6530)

FEASIBILITY STUDY OF A CAPACITANCE-TYPE ELECTRONIC SEDIMENT-SENSING DEVICE.

- (b) Soil and Water Conservation Research Div., Agric. Research Service, U. S. Dept. Agric.
- (c) C. Earl Israelsen, Research Engr.
- (d) Experimental; applied research.
- (e) Electrical capacitance between plates submerged in water is proportional to the dielectric constant of the water-sediment mixture. The value of the dielectric constant can be an indication of the sediment present. An investigation is being made to determine the feasibility of this method for measuring sediment concentration.
- (f) Completed.
- (g) (1) The capacitance method of measuring concentrations of sediment in natural streams is not practical, primarily because of the fact that the presence of even small quantities of conducting and/or magnetic sediments in the measured samples invalidates the measurements; (2) the capacitance method of measurement may be applicable for particular or specialized uses, such as the determination in the laboratory of concentrations of mixtures of known non-conducting and nonmagnetic particulate matter. Such measurements are not noticeably affected by the salts used in this study until their concentrations exceed about 10 milliequivalents/liter.
- (h) The report to the supporting agency is not available for general distribution.

(6531)

HYDROLOGIC ATLAS OF UTAH.

- (b) Office of Water Resources Research and Utah Water and Power Board.
- (c) Roland W. Jeppson, Associate Professor.
- (d) Applied research.
- (e) The objective is to analyze and evaluate existing hydrologic and climatologic data of Utah to determine the magnitude of the available water resources and their spatial and time variations. The data will be reduced to maps, charts, graphs, and tables carefully developed for easy understanding and simplicity of use.
- (f) Completed.
- (h) "Hydrologic Atlas of Utah," Utah Water Research Lab., Utah State Univ., Nov. 1968. Price \$10. "Estimating Water Yields in Utah by Principal Component Analysis," Report No. PRWG 35a-1, Utah Water Research Lab., Utah State Univ., June 1967.

(7726)

SUBCRITICAL FLOW AT OPEN CHANNEL STRUCTURES.

- (b) Office of Water Resources Research and Utah State Univ.
- (c) Lloyd H. Austin, Research Engineer.
- (d) Experimental.
- (e) The research accomplished under the previous matching fund grant, "Design and Calibration of Submerged Open Channel Flow Measurement Structures," will be extended to include additional practical physical situations, and to seek more answers to certain basic open channel flow problems. The previous research project showed that the methods of subcritical flow analysis are

applicable to any form of side constriction or floor constriction. In addition, the special case of zero constriction will be studied in the laboratory to determine if the methods of analysis are applicable for describing flow resistance in open channels under steady nonuniform flow conditions. A large amount of data collected by previous investigators regarding the hydraulics of bridge constrictions will be evaluated using the techniques developed to date. The evaluation will include the hydraulic design of bridge constrictions and the collection of discharge measurements at bridge constrictions. The analytical tools developed to date will also be applied to developing hydraulic design criteria for open channel expansion.

(7727)

A THEORETICAL STUDY OF INFILTRATION INTO RANGE AND FOREST SOILS.

- (b) Forest Service, U. S. Dept. of Agriculture.
- (c) Joel E. Fletcher, Professor of Hydrology.
- (d) Project is largely theoretical but tied to experimental data.
- (e) Infiltration curves and soil properties for a number of field soils are being compared to several theoretically derived equations in order to test their compliance to actual measurements.

(7728)

NUMERICAL EVALUATION OF WALL EFFECTS ON AXISYMMETRIC CAVITY FLOWS.

- (b) Office of Naval Research; Naval Ship Res. and Dev. Center.
- (c) Roland W. Jeppson, Assoc. Prof.
- (d) Basic research.
- (f) Completed.
- (g) Finite difference methods are utilized in solving the nonlinear inverse boundary value problem for modeling the axisymmetric, inviscid cavity flows past disks. The Riabouchinsky Model is utilized in the formulation of the problems. The results from a number of solutions for both the problem in which the disk is placed in a free surface jet and for the problem in which the disk is placed within a flow confined in a constant radius conduit are analyzed, and parameters commonly used to characterize such flows are correlated to indicate the influence of the continuing boundary on this type of cavity flow.
- (h) "Finite Difference Solutions to Free Jet and Confined Cavity Flows Past Disks with Preliminary Analyses of the Results," Report No. PRWG 76-1, Utah Water Research Lab., Utah State Univ., Nov. 1969.

(7729)

THREE-DIMENSIONAL FREE SURFACE POTENTIAL FLOWS.

- (b) National Science Foundation.
- (c) Roland W. Jeppson, Assoc. Prof.
- (d) Theoretical applied research.
- (e) Free surface potential fluid flows are to be formulated in the space defined by two mutually orthogonal stream functions and the potential function for the cartesian coordinates x, y and z as the dependent variables. In this space free surfaces are planes making possible the formulation of partial differential equation boundary value problem on a defined region. The boundary value problems will be solved by finite difference methods.

(7730)

WATERSHED INFILTRATION AND THE RESULTING FLOW SYSTEM.

- (b) Agricultural Research Service - cooperative

- agreement.
- (c) Roland W. Jeppson, Assoc. Prof.
 - (d) Basic-applied research.
 - (e) Infiltration characteristics of watershed soils are being studied by formulating initial value and boundary value problems with partial differential equations which result by considering fundamental soil properties and their influence on the unsaturated-saturated soil water flow system.
 - (h) "Numerical Solution of the Steady-State Two-Dimensional Flow System Resulting from Infiltration on a Watershed," Rept. No. PRWG 59c-1, Utah Water Research Lab., Utah State Univ., June 1969. "Theoretical and Experimental Aspects of Watershed Infiltration in Terms of Basic Soil Properties," CSC 6810-1, Computer Sciences Corp., Richland, Wash., Utah Water Resources Lab., Utah State Univ., Oct. 1968.
- (7731)
INFLUENCE OF MOUNTAIN GROUNDWATER ON STREAMFLOW.
- (b) Environmental Science Service Admin.
 - (c) Roland W. Jeppson, Assoc. Prof.
 - (d) Applied research.
 - (f) Completed.
 - (g) The study has dealt with theory and methods for separating the groundwater component from the total streamflow hydrograph, and describing the magnitude of this component by an equation based on the assumption that discharge from groundwater is a linear function of the volume of water in storage. By utilizing this equation to forecast the groundwater contribution on a continuous basis and forecasting the surface runoff component by regression equations patterned after the current forecasting procedure, a total stream forecast methodology has been developed which in tentative test shows considerable improvement over present methods.
 - (h) "Influence of Mountain Groundwater on Streamflow," Rept. No. PRWG 75-1, Utah Water Research Lab., Utah State Univ., March 1970.
- (7732)
HYBRID COMPUTER SIMULATION AS APPLIED TO THE MANAGEMENT OF WATER SALINITY WITHIN A HYDROLOGIC SYSTEM.
- (b) Office of Water Resources Research.
 - (c) Dr. J. Paul Riley, Assoc. Prof., and Eugene K. Israelsen, Research Engineer.
 - (d) Theoretical and experimental; applied research for Ph.D. thesis.
 - (e) The objectives of the research are to derive, test and refine fundamental relationships relating the hydrologic and salinity flow systems. The hybrid computer will be used to demonstrate the applicability of the hydro-salinity model to salinity management in water resource systems.
- (7733)
ELECTRONIC ANALOG SIMULATION OF THE PAEZ-PEDRAZA REGION OF VENEZUELA.
- (b) Corporacion de Los Andes, Government of Venezuela.
 - (c) Dr. J. Paul Riley, Assoc. Prof.
 - (d) Theoretical and experimental; applied research for a M. S. thesis.
 - (e) The primary objective of this research was to develop a simulation model of the hydrologic system within a large drainage area of central Venezuela. The model was then used for estimating runoff rates from ungaged subareas and for testing the sensitivity of the system to changes in certain parameters and hydrologic processes. The project also established the feasibility of conducting additional and more detailed simulation investigations for water resource management in Venezuela and other South American countries.
- (f) Completed.
- (h) "Electronic Analog Simulation of the Paez-Pedraza Region of Venezuela," J. Paul Riley, V. V. Dhruva Narayana and Kousoum Sakhan, PRWG 65-1, Utah Water Research Lab., Utah State Univ., Feb. 1969.
- (7734)
HYBRID COMPUTER SIMULATION OF THE SNOW ACCUMULATION AND MELT PROCESSES.
- (b) U.S. Bureau of Reclamation and Environmental Science Services Administration.
 - (c) Dr. J. Paul Riley, Assoc. Prof.
 - (d) Theoretical and experimental; applied research for Ph.D. dissertation and M.S. theses.
 - (e) The basic objective of this research is to develop a fundamental and reliable simulation model of the snowmelt process which will have practical application in both seasonal and short-term runoff predictions. The hybrid computer is being used for this study.
 - (h) "Hybrid Computer Simulation of the Snow Accumulation and Melt Processes," Keith Eggleston, J. Paul Riley and Eugene K. Israelsen, Utah Water Research Lab., Utah State Univ., PRWG 65-1, April 1970.
- (7735)
DESCRIBING AND CONFIRMING A BASIC NATURAL GROUNDWATER-SURFACE WATER INTERCHANGE PHENOMENON USING HYBRID COMPUTER SIMULATION.
- (b) U. S. Dept. of the Interior, Federal Water Pollution Control Admin.
 - (c) Dr. J. Paul Riley, Assoc. Prof.
 - (d) Theoretical and experimental; applied research for a Ph.D. dissertation and a M. S. thesis.
 - (e) The major objective of this study is to develop a fundamental understanding of the salinity flow system within a hydrologic basin, and then provide a means of differentiating between the natural and agricultural contributions under irrigated conditions. The basic processes will be expressed in mathematical terms and a hybrid computer model developed. The model will be verified and tested using field data from sub-basins within the Upper Colorado River drainage.
- (7736)
COMPUTER SIMULATION ON A TECHNIQUE FOR THE MANAGEMENT OF WATER SALINITY WITHIN A RIVER SYSTEM.
- (b) Agricultural Experiment Station, Utah State Univ.
 - (c) Dr. J. Paul Riley, Assoc. Prof.
 - (d) Theoretical and experimental; applied research for a M. S. thesis and a Ph.D. dissertation.
 - (e) The primary purpose of this project is to develop simulation model of the hydrologic and salinity flow system within the Sevier River drainage of central Utah. The model will be verified using hydrologic and salinity data from the Sevier River basin. The model will then be used for conducting sensitivity studies and for testing various alternatives for the management of the salt load within the system.
- (7737)
DEVELOPING A DETERMINISTIC, DISTRIBUTED NON-LINEAR SURFACE-GROUNDWATER MODEL FOR THE ATLANTICO 3 PROJECT, COLOMBIA, SOUTH AMERICA.
- (b) U.S. Agency for International Development.
 - (c) Dr. J. Paul Riley, Assoc. Prof.
 - (d) Theoretical and experimental; applied research for M.S. theses and Ph.D. dissertations.
 - (e) The primary purpose of this research is to develop a simulation model of the joint hydrologic-economic

system for the project area. The hydrologic model will include detailed definition of groundwater flow in both the unsaturated and saturated zones. The model will then be used to test various management alternatives under differing conditions of irrigation application rates and vegetative cover (both native and cultivated).

(7738)

THE RELATION OF DISPERSION TO BOUNDARY ROUGHNESS IN STEEP, ROUGH CHANNELS.

- (c) Gary Z. Watters, Assoc. Prof., Dept. of Civil Engineering.
- (d) Experimental; basic and applied research; Ph.D. dissertation.
- (e) Flow in steep rough channels such as mountain streams has not been studied enough in detail. The flow resistance depends not only on boundary roughness, but also slope and depth of flow. This project will be concerned with measuring the dispersive properties of a given flow and relating these properties to the flow resistance. For a stream of known flow resistance, this would provide information on the dispersion. For a stream of unknown flow resistance, the dispersive properties can easily be measured with dye and the flow resistance evaluated.

(7739)

CIRCULATION IN DENSITY-STRATIFIED WASTE STABILIZATION PONDS.

- (b) Center for Water Resources Research.
- (c) Gary Z. Watters, Assoc. Prof., Dept. of Civil Engineering.
- (d) Experimental; basic and applied research for Ph.D. dissertation.
- (e) Realistic design procedures for the hydraulic behavior of waste stabilization ponds are virtually non-existent. Short-circuiting is known to occur and inefficient treatment in "dead" portions of the pond result in poor waste treatment. In this work a model of the pond is constructed and inflow to the pond will be of different density than the pond itself. Circulation patterns will be observed and different types of entrance and outlet structures will be tried to improve pond circulation characteristics. The result should provide more realistic guidelines for waste stabilization pond design.

(7740)

THE EFFECTS OF WIND ON CIRCULATION AND DISPERSION IN A SHALLOW DENSITY-STRATIFIED POND.

- (b) Center for Water Resources Research.
- (c) Gary Z. Watters, Assoc. Prof., Civil Engineering Dept.
- (d) Experimental; for Ph.D. dissertation, basic research.
- (e) The effects of wind on the circulating patterns and the dispersive characteristics in density stratified shallow bodies of water is not well-known. In this work a long shallow tank is constructed and filled with a density stratified fluid. Air is then drawn across the surface and the development of two-dimensional circulation patterns is observed. The results should indicate the importance of wind as a factor influencing dispersion in shallow ponds.

VANDERBILT UNIVERSITY, Department of Environmental and Water Resources Engineering, Nashville, Tennessee 37203. Dr. Peter A. Krenkel, Department Chairman and Professor.

(6165)

TURBULENT DIFFUSION AND REAERATION IN NATURAL RIVERS.

- (b) Federal Water Pollution Control Admin.
- (c) Dr. Edward L. Thackston, Assistant Professor.
- (d) Laboratory and field studies are conducted to test and demonstrate theoretical predictions, previously derived, and to indicate direction for further theoretical work. The project includes both basic and applied research and demonstration of usefulness and applicability of results. Both M.S. and Ph.D. theses may result from the work.
- (e) The project objectives are (1) to measure reaeration rates and relevant turbulence parameters in selected rivers under controlled conditions; (2) to test the applicability of recently developed theoretical mathematical models describing reaeration and mixing in natural rivers, and (3) to determine the utility of refined tracer techniques in describing mixing phenomena in unsteady-state flow conditions and stratified flow.
- (g) The applicability of a recently developed model of mixing in open-channel flow incorporating tracer technique storage in dead zones to natural streams has been demonstrated. Methods for the prediction of the parameters in the mathematical model from basic hydraulic data have been developed. Tracer tests have been conducted in interflows in stratified reservoirs, and procedures for calculating various mixing coefficients were demonstrated. It was shown that essentially no mass transfer across a thermocline occurs.
- (h) "The Influence of Impoundments on Waste Assimilative Capacity," Peter A. Krenkel, Edward L. Thackston, and Frank L. Parker, Current Research into the Effects of Reservoirs on Water Quality, Proc., ASCE Specialty Conf., Jan. 1968, pp. 1-39. "Impoundment and Temperature Effect on Waste Assimilation," Peter A. Krenkel, Edward L. Thackston, and Frank L. Parker, J. San. Engrg. Div., ASCE, Vol. 95, No. SA1, pp. 37-64, Feb. 1969. "Tracing Polluted Reservoir Inflows with Fluorescent Dyes," Michael W. Morris and Edward L. Thackston, Tech. Rept. No. 21 in Environmental & Water Resources Engrg., Vanderbilt Univ., 1969, 61 pp.

(7741)

TEMPERATURE DISTRIBUTIONS RESULTING FROM COOLING WATER DISCHARGES.

- (b) Federal Water Pollution Control Admin.
- (d) Laboratory and field investigations are conducted to test and demonstrate theoretical predictions and to indicate directions for further theoretical work. Both basic and applied research are included, and both M.S. and Ph.D. theses should result from the work.
- (e) There is a paucity of data on mixing zones below thermal power plants. Adequate and varied field data is needed to verify the various models which have been proposed. Field data gathered from a wide range of field sites will be used to test several models, including one developed within the project. Laboratory data will also be obtained. The diffusion model presently proposed will be modified to include reflections from river banks. Attempts will be made to acquire data on the non-conservative, cooling case as well as conservative problems.
- (g) Field data has been gathered for temperature distributions in the vicinity of cooling water discharges. Applicability of Bata's wedge solution has been verified with slight modification if initial mixing is accounted for. Diffusion models

- have been prepared relating surface areas and cross-sectional areas within a given temperature contour to basic flow parameters. Field data has been used to evaluate the diffusion coefficient in the model.
- (h) "Initial Mixing of Thermal Discharges into a Uniform Current," John Eric Edinger and Edward M. Polk, Jr., Tech. Rept. No. 1, National Center for Research and Training in the Hydrologic and Hydraulic Aspects of Water Pollution Control, Oct. 1969, 45 pp.
- "Progress Report," Peter A. Krenkel and Frank L. Parker, Tech. Rept. No. 2, National Center for Research and Training in the Hydrologic and Hydraulic Aspects of Water Pollution Control, Oct. 1969, 152 pp.
- (7742)
HEATED SURFACE JETS DISCHARGED INTO FLOWING AMBIENT.
- (b) Federal Water Pollution Control Admin.
(c) Dr. B. A. Benedict, Assistant Professor.
(d) Theoretical; applied research; Ph.D. thesis to result from work.
- (e) The project objectives are (1) the development of a momentum jet model describing the distribution of temperature from heated discharges, (2) to test this model with field data, and (3) to acquire laboratory data for relation of needed coefficients to basic flow parameters.
- (g) A two-dimensional surface jet model has been developed including an entrainment coefficient and a drag coefficient. The model is valid for any angle of jet to ambient flow. These coefficients have been studied in laboratory work; also observed was the length of the zone of flow establishment. Applicability of the model to field conditions is also being tested, with reasonable results for limited data. Knowledge of the ratio of jet to ambient velocities, initial jet angle, and other basic characteristics enables coefficient determination and model application.
- (h) "Progress Report," Peter A. Krenkel and Frank L. Parker, Tech. Rept. No. 2, National Center for Research and Training in the Hydrologic and Hydraulic Aspects of Water Pollution Control, Oct. 1969, 152 pp.

- (7743)
DISCHARGE OF NEGATIVELY BUOYANT FLUIDS.
- (b) Federal Water Pollution Control Admin.
(c) Dr. Frank L. Parker, Professor.
(d) Experimental, theoretical; applied research; M.S. and Ph.D. theses to result.
- (e) The project seeks to study mixing of negatively buoyant jets discharged from submerged diffusers. The study will include: (1) acquisition of laboratory data for varying densimetric Froude numbers, jet angle, and jet ports; (2) observation of height of rise and distance required to achieve full mixing; (3) development of a theoretical model to enable prediction.
- (g) Laboratory data and model development currently underway.

- (7744)
HEAT TRANSFER IN FLOWING WATERS.
- (b) Federal Water Pollution Control Admin.
(d) Experimental; basic and applied research; Ph.D. thesis to result.
- (e) This project seeks to study the influence of the intensity of turbulence (especially at the air-water interface) on the rate of thermal exchange between the water and the atmosphere. Expected similarity to gas transfer research suggests laboratory scale studies. Laboratory work will

- consist of (1) small scale-studies in lab vessels utilizing a stirrer to induce turbulence; (2) measurements in a laboratory flume.
- (g) Theoretical background being prepared; testing underway.

VIRGINIA POLYTECHNIC INSTITUTE, College of Engineering, Department of Civil Engineering, Blacksburg, Virginia 24061. Dr. H. M. Morris, Department Head.

- (5533)
USE OF LARGE ROUGHNESS ELEMENTS FOR HYDRAULIC ENERGY DISSIPATION.
- (b) Virginia Council of Highway Investigation and Research and Federal Highway Administration.
- (d) Analytical and experimental, supplemented by field studies; basic and applied research.
- (e) Studies are being made to develop general design criteria for flow regimes and energy dissipation in steep channels with large roughness elements. The characteristics of the "tumbling-flow" regime are of special interest. Design applications for chutes, culverts, and other highway drainage structures are in view.
- (f) Completed.
- (h) "Hydraulics of Energy Dissipation in Steep, Rough Channels," Henry M. Morris, Bull. 19, V.P.I. Research Div., Nov. 1968, 108 pp.
- "Design of Roughness Elements for Energy Dissipation in Highway Drainage Chutes," Henry M. Morris, Highway Research Record, No. 261, May 1969, pp. 25-37.
- "Tumbling Flow in Open Channels," Henry M. Morris and J. Sterling Jones, Preprint 1124, A.S.C.E. Natl. Water Resources Engrg. Meeting, Memphis, Tenn., Jan. 1970, 43 pp.

- (6279)
ANALYSIS OF HYDROLOGIC SYSTEMS.
- (b) Office of Water Resources Research.
(c) Dr. J. M. Wiggert, Assoc. Prof.
(d) Analytical and experimental; basic and applied research; Ph.D. thesis.
- (e) This study examines the hydrologic runoff process in terms of fundamental systems analysis. Investigated is the response (discharge) of systems of simple configuration to inputs (rainfall) of simple description. Time constants and amplitude derived from data are used for a synthesis of other flows. Application of the method to data from natural watersheds is also being made.
- (f) Completed.
- (h) "Analysis of Hydrologic Systems," Tsung Ting Chiang, Ph.D. dissertation, Virginia Poly. Inst., Jan. 1968.
- "Analysis of Hydrologic Systems," Tsung Ting Chiang and J. M. Wiggert, Bull. 12, Water Resources Research Center, Virginia Poly. Inst., May 1968.

- (6280)
MOTION OF A PARTICLE IN POISEUILLE FLOW.
- (c) Dr. J. M. Wiggert.
(d) Analytical and experimental; basic research; M.S. thesis.
- (e) A study of the transverse forces on and motion of single particles, both leading and lagging fluid flowing laminarily in a tube.
- (f) Completed.
- (h) "The Existence of a Two-way Radial Force Field on a Static Sphere Suspended in Poiseuille Flow," G. A. Beasley, M.S. thesis, Virginia Poly. Inst., March 1968.

(7745)

ENERGY DISSIPATION IN PIPE CULVERTS.

- (b) American Concrete Pipe Association.
- (d) Analytical and experimental; basic and applied research.
- (e) Studies are being made to develop the basic relations and design criteria governing the action and use of roughness elements in circular pipe culverts flowing part full. The purpose of the roughness elements is to dissipate the kinetic energy of the flow in the barrel of the culvert.

VIRGINIA POLYTECHNIC INSTITUTE, College of Engineering, Department of Engineering Mechanics, Blacksburg, Virginia 24061. Dr. Daniel Frederick, Department Head.

(7746)

VISCOUS FLOWS IN HIGH SPEED FLIGHT - A STUDY OF SECOND-ORDER BOUNDARY LAYER EFFECTS.

- (b) Office of Naval Research.
- (c) Professor R. T. Davis or Assistant Professor M. J. Werle.
- (d) Theoretical, basic research.
- (e) This study concerns the influence of second-order boundary layer effects on several viscous flow problems. To date this effort has concentrated on the treatment of displacement thickness and curvature effects as first order contributors to the boundary layer development over curved surfaces in moderate to low Reynolds number flows.
- (g) A set of governing equations consistent to second-order have been derived. For the compressible case, these equations show that previous studies of this problem have omitted several significant viscous terms.
- (h) "The Development of an Incompressible Boundary-Layer Theory Valid to Second Order," R. T. Davis, R. E. Whitehead, S. F. Wornom, Virginia Poly. Inst. Rept. VPI-E-70-1, Jan. 1970.
"A Consistent Formulation of Compressible Boundary-Layer Theory with Second-Order Curvature and Displacement Effects," R. T. Davis, M. J. Werle, and S. F. Wornom, submitted to AIAA Journal.

(7747)

HYDRODYNAMIC STABILITY OF PARALLEL FLOWS OF SECOND-ORDER LIQUIDS.

- (b) National Science Foundation.
- (c) Asst. Prof. Dean T. Mook.
- (d) Theoretical, basic research.
- (e) This study is concerned with the influence of the viscoelastic properties of some liquids on the stability of parallel, or nearly parallel, flows and with the development of better methods for calculating neutral stability curves. Infinitesimal disturbances are considered.
- (g) A new finite-difference procedure has been developed and neutral stability curves for Couette-Poiseuille flow for various second-order liquids have been calculated. The use of a variational method to solve for neutral stability curves has also been developed and an asymptotic solution, with viscoelastic effects included, has been found.
- (h) "The Stability of Parallel Flows of Viscoelastic Liquids Between Plates at Rest: An Asymptotic Solution," D. T. Mook and W. P. Graebel, Va. Poly. Inst. Rept. VPI-E-70-7, Jan. 1970.

VIRGINIA POLYTECHNIC INSTITUTE, Department of Mechanical Engineering, Blacksburg, Virginia 24061. Dr. J. B. Jones, Department Head.

(6194)

- LATERAL FLOW REVERSAL IN STRONGLY SKEWED, PRESSURE DRIVEN THREE-DIMENSIONAL TURBULENT BOUNDARY LAYERS.
- (b) Army Research Office - Durham.
 - (c) Dr. F. J. Pierce; Assoc. Prof.
 - (d) Experimental; basic research.
 - (e) The existence and nature of the reversal of lateral or skewed flow in a pressure driven three-dimensional turbulent boundary layer was examined. Lateral flow reversal was obtained in a recurving or S shaped rectangular channel.
- (f) Completed.
- (h) "Secondary Flow Reversal and Velocity Profile Models in a Three-Dimensional Turbulent Boundary Layer," F. J. Pierce and W. F. Klinksiek, Interim Tech. Rept. No. 1, AROD Project No. 6858E, Contract No. DAH-C04-67-C-0008, Aug. 1968.
"Simultaneous Lateral Skewing in a Three-Dimensional Turbulent Boundary Layer Flow," F. J. Pierce and W. F. Klinksiek, ASME Paper 69 FE-24, to be published in J. Basic Engrg., Trans. ASME.

(7748)

TURBULENT SHEAR STRESS DISTRIBUTIONS IN THREE-DIMENSIONAL TURBULENT BOUNDARY LAYERS.

- (b) Army Research Office - Durham.
 - (c) Dr. F. J. Pierce.
 - (d) Experimental.
 - (e) Time average velocity field and pressure field data are used with a partial control volume analysis to infer the streamwise and transverse turbulent shear stress variations through a strongly skewed flow. Hot-film anemometer techniques were used to measure these same distributions also.
- (f) Completed.
- (h) In preparation for publication.

(7749)

PROPULSIVE CHARACTERISTICS OF UNDULATING PLATE-TYPE PROPELLERS.

- (b) National Science Foundation.
 - (c) Dr. A. G. Szeless, Asst. Prof.
 - (d) Experimental; applied research; for master's thesis.
 - (e) The thrust characteristics of an underwater undulating plate were determined with free stream velocity, plate size and stiffness, and excitation frequency and amplitude as parameters.
- (f) Completed.

(7750)

TURBULENCE PROPERTIES IN STRONGLY SKEWED THREE-DIMENSIONAL TURBULENT BOUNDARY LAYERS.

- (b) Army Research Office - Durham.
- (c) Dr. F. J. Pierce.
- (d) Experimental.
- (e) Hot-wire anemometry techniques are being used to measure a variety of turbulence properties in a skewed three-dimensional turbulent boundary layer flow. Detailed measurements of all elements of the stress tensor, energy spectra, etc., will be gathered. Relationships between streamwise and transverse shear stresses and turbulent energy will be examined.

(7751)

NUMERICAL SOLUTIONS TO THREE-DIMENSIONAL TURBULENT BOUNDARY LAYER FLOWS.

- (b) Army Research Office - Durham.
- (c) Dr. F. J. Pierce.

- (d) Analytical; basic research.
- (e) A momentum integral solution for the boundary layer on the bounding wall of an impinging jet flow has been generated after the work of Cumpsty and Head, utilizing the Head entrainment function concept. Comparison with existing experimental data is made. A finite difference solution to this same flow field is being made after the Dufort-Frankel scheme. Solutions to the governing equations on the plane of symmetry compare well with the experimental results of Johnston and the analytical work of Mellor. Calculations off the plane of symmetry are now being made.
- (h) In preparation for publication.

(7752)

FEASIBILITY STUDY OF METHODS FOR THE ACCURATE DETERMINATION OF HYDRODYNAMIC FORCES ON STRANDED CABLES.

- (b) Naval Research Laboratory (ONR).
- (c) Dr. H. L. Moses, Assoc. Prof.
- (d) Experimental study for Master's thesis.
- (e) The objective of this study is to develop an accurate method of measuring drag and lift forces on stranded cables as a function of cable geometry, Reynolds number, and angle of attack.

(7753)

FLUIDIC SIGNAL TRANSMISSION AND NOISE IN INTEGRATED CIRCUITS.

- (b) Corning Glass Works.
- (c) R. A. Comparin, Professor, and H. L. Moses, Assoc. Prof.
- (d) Analytical and experimental study for master's thesis.
- (e) The objective of this study is to develop information on signal transmission and noise generation that can be used directly in the design of multi-layer integrated fluidic circuits.

UNIVERSITY OF VIRGINIA, Chemical Engineering Department, Charlottesville, Virginia 22901. Dr. V. W. Uhl, Department Chairman.

(7754)

STABILITY OF MULTIPHASE FLOWS IN NON-CIRCULAR CONDUITS.

- (c) Dr. L. U. Lilleleht, Assoc. Prof.
- (d) Experimental and theoretical; basic and applied research; master's theses.
- (e) Investigation of laminar flow stability and transition to turbulence in stratified liquid-liquid flows in rectangular conduits.
- (f) Temporarily suspended due to lack of funding.
- (g) Hot-film anemometry measurements have been made to investigate the laminar-turbulent transition process in stratified two-liquid systems. Interfacial structure has been measured by light absorption and photographic techniques. Existing single phase criteria for transition to turbulence have been modified for the two-liquid case. Design relations for transitional flow regime are proposed.
- (h) "Laminar-Turbulent Transition in Two-Phase Stratified Flow," H. D. Spriggs, Master's thesis, Univ. of Virginia Library, June 1968.
"The Transition to Turbulence in Two-Phase Flow," P. J. Leider, Master's thesis, Univ. of Virginia Library, May 1969.
"Interfacial Structure of Oil-Water Flow in a Rectangular Conduit," R. G. McClung, Master's thesis, Univ. of Virginia Library, June 1969.

(7755)

BLOOD FLOW MODELING.

- (b) National Heart Institute, Artificial Heart Program.
- (c) Dr. L. U. Lilleleht, Assoc. Prof.
- (d) Predominantly experimental; basic and applied research.
- (e) A semi-transparent suspension of flexible-walled microcapsules has been developed to simulate the flow behavior of whole blood. Flow patterns and stability of this "pseudo-blood" are being investigated in various rigid and distensible conduits containing obstructions and bifurcations.
- (g) Flow patterns have been investigated by flow visualization techniques and recorded by high speed cinephotography in 1/2-inch diameter distensible walled vessels using the "pseudo-blood" suspensions with microcapsule concentrations up to 35 volume percent. Both steady and pulsatile flow have been used. Measurements are also available for transition to turbulence in steady flow.
- (h) "Blood Flow Modeling with Microcapsular Suspensions," R. M. Navari, M.ChE. thesis, Feb. 1968 (U. Va. Library).
"Studies of Blood Flow in and Adjacent to Blood Pumps," S. M. Scala, N. R. Kuchar, M. P. Sherman, P. Gordon and L. U. Lilleleht, Proc. Artificial Heart Program Conf., pp. 309-329, June 9-13, 1969, Washington, D.C., U.S. Dept. H.E.W., Natl. Inst. of Health.

WASHINGTON STATE UNIVERSITY, The R. L. Albrook Hydraulic Laboratory, Pullman, Washington 99163. John F. Orsborn, Laboratory Head.

(6157)

CLAY SLURRY FLOW CHARACTERISTICS.

- (b) J. R. Simplot Co., Bovill, Idaho.
- (f) Completed.

(6159)

HYDRAULIC STUDIES OF FLOATING BREAKWATERS.

- (b) U.S. Forest Service, Seattle, Washington.
- (d) Experimental; applied research.
- (e) The design and fabrication of a wave basin was completed for the purpose of studying the effectiveness of floating breakwaters. Investigations are being made with the idea of using floating breakwaters along the southeast coast of Alaska. The log breakwaters are being investigated as opposed to towing more permanent and costly steel floating breakwaters from one loading site to another. Three designs will be tested for maximum and mean wave heights for the vicinity. Mooring forces on the anchors will be determined.
- (f) Completed.

(6164)

SPILLWAY CHARACTERISTICS FOR FISH PASSAGE.

- (b) U.S. Army Corps of Engineers.
- (c) Howard D. Copp, Assoc. Hydraulic Engineer.
- (d) Analytical; applied research.
- (e) Analytical studies are being conducted to analyze water passage over existing spillways and associated stilling basins of hydroelectric power projects. End results are a determination of acceptable and harmful characteristics of said spillways with regard to downstream fish migration.
- (f) Completed.
- (h) "Stilling Basin Hydraulics and Downstream Fish Migration," Howard D. Copp, Research Rept. No. 68/9-47, Coll. of Engrg. Research Div., Washing-

(7756)

CONTROLLING THE LOCATION AND DISPERSION OF THERMAL POLLUTING EFFLUENTS.

- (b) Office of Water Resources Research.
- (c) Claud C. Lomax, College of Engrg. Research Div.
- (d) Experimental and theoretical; basic research.
- (e) The research is to study the significance of controlling the location and the dispersion of a heated effluent discharged into a natural stream. In the laboratory a dyed effluent will be injected into an open channel stream and the dispersion and location of the pollutant traced using photographic and fluorometric techniques. A fluorescein dye will be used as the pollutant. These parameters will be investigated: (1) velocity and direction of the effluent stream at entry; (2) controls on the effluent at its point of entry to restrict turbulence and mixing with the main stream.

(7757)

RUNOFF GENERATION IN WESTERN WASHINGTON AS A FUNCTION OF PRECIPITATION AND WATERSHED CHARACTERISTICS.

- (b) U.S. Dept. of Interior, Office of Water Resources Research.
- (c) John S. Gladwell, Assoc. Hydraulic Engineer.
- (d) Statistical analysis of field data; basic research (used for doctoral dissertation).
- (g) Watershed hypsometry can be shown to be highly correlated to mean annual discharge, and can also be used to predict quite accurately the mean annual hydrograph. The standard deviation of runoff has been shown to be generally predictable on the basis of precipitation data. It is also found to be linearly related to the mean annual discharge. Skewness and kurtosis of annual precipitation are found to be roughly definable by geographic delineations. Runoff skewness is generally less than that of precipitation; kurtosis of runoff is less easily defined, but generally has a value of less than three. Annual precipitation appears to be serially correlated; the correlogram of runoff is found to be related to that of precipitation. Cross-correlations of precipitation and of runoff are found to be functions of proximity and a directional component.
- (h) Completion report will be available after June 1970. A paper on the mean monthly hydrograph will be presented at the Int. Water Erosion Symp., Prague, Czechoslovakia, June 1970.

(7758)

HEAT TRANSFER MECHANICS OF RESERVOIRS AND LAKES.

- (c) Howard D. Copp, Assoc. Hydraulic Engineer.
- (d) Theoretical; basic and applied research; operation and development.
- (e) Simulation techniques are being developed for energy transfer mechanics and heating phenomena in shallow, unstratified water bodies. Establishment of a field "laboratory" is contemplated to verify techniques. Design and operation of recreation and fish rearing facilities are the primary objectives of the research.

(7759)

HYDRAULIC MODEL STUDIES OF ROSS DAM SPILLWAY MODIFICATIONS.

- (b) City of Seattle, Washington, Department of Lighting (International Engineering Co., Inc.).
- (c) Howard D. Copp, Assoc. Hydraulic Engineer.
- (d) Experimental; applied research; design and operation.

- (e) A 1:48 scale hydraulic model was fabricated to study spillway designs and operations contemplated by planned enlargement of the Ross Dam on the Skagit River in western Washington. A 125-foot increase in the dam's height would require new spillways and discharge chutes.
- (h) Report in preparation.

(7760)

MIDDLE SNAKE RIVER WATER TEMPERATURE.

- (b) Pacific Northwest Power Company.
- (c) Howard D. Copp, Assoc. Hydraulic Engineer.
- (d) Theoretical; applied research; operations.
- (e) Cursor investigations were made to determine if proposed hydropower projects could be operated to regulate downstream water temperatures.
- (f) Completed.
- (h) "Predicted Outflow Temperatures from the Proposed Pleasant Valley Reservoir with Selective Withdrawal from the Brownlee Reservoir." Howard D. Copp, Research Rept. 69/9-57, Coll. of Engr. Research Div., Washington State Univ., Nov. 1969.

(7761)

WATER TEMPERATURE PREDICTIONS FOR TURTLE ROCK ISLAND FISH REARING POND COLUMBIA RIVER NEAR WENATCHEE, WASHINGTON.

- (b) Public Utility District No. 1 of Chelan County, Washington.
- (c) Howard D. Copp, Assoc. Hydraulic Engineer.
- (d) Theoretical; basic and applied research; operations.
- (e) Predictions, by computer simulation, of water temperatures in a fish rearing pond were developed to determine necessary flow-through quantities.
- (f) Completed.
- (h) "Water Temperature Predictions for Turtle Rock Island Fish Rearing Pond Columbia River Near Wenatchee, Washington," Howard D. Copp, Research Rept. 69/6-67, Coll. of Engr. Research Div., Washington State Univ., Oct. 1969.

(7762)

FLUSHING OF SMALL SHALLOW LAKES.

- (b) Federal Water Pollution Control Admin.
- (c) Claud C. Lomax, Hydraulic Engineer.
- (d) Experimental and theoretical; basic research.
- (e) The research is being carried out to determine the time required to flush an elliptically shaped lake of pollutants by an inflow of clean water. The volume of flushing water and lake volume are being compared. Parameters such as depth and basin shape are also being investigated.
- (g) A digital computer program has been developed to obtain residual concentrations at any time after test begins.

(7763)

HYDRAULIC MODEL STUDY OF A FISH GUIDANCE SCREEN.

- (b) U.S. Bureau of Commercial Fisheries.
- (c) August C. Mueller, Asst. Hydraulic Engineer.
- (d) Theoretical and experimental.
- (e) Flow and head loss through a powerhouse intake passageway with a traveling fish guidance screen installed in the vicinity of the emergency gate slots. Purpose was to optimize operation conditions in order to best guide downstream migrant anadromous fish while minimizing head loss in the flow system. Drag forces determined for various angles of screen to flow.
- (f) Suspended.
- (g) Flow stream lines were found to be very similar to conditions without the screen in place. The major difference observed was that the vertical flow profile was modified. The flow pattern in

- the gatewell was found to be considerably changed making it somewhat less conducive to retaining fish in the gatewell area.
- (h) "Hydraulic Model Studies of a Fish Guidance Screen," A. C. Mueller and J. F. Orsborn, Research Rept. No. 69/9-75, Coll. of Engr. Research Div., Washington State Univ., July 1969.
- (7764)
RIVER ENGINEERING.
- (d) Theoretical; applied research.
- (e) Literature review and personnel survey of problems involving hydraulic engineering design associated with mountain streams. Personnel with the U.S. Forest Service will be contacted regarding analysis and design of structures such as bridges, culverts, roads and river bank protection.
- (7765)
EVALUATION OF TRASHRACK DESIGN CRITERIA.
- (b) Public Utility District No. 1 of Chelan County, Washington.
- (d) Theoretical; applied research.
- (e) In the past, design of trashracks has not taken into account the shape of and losses caused by various structural support and brace members. The members were analyzed and tested individually to find how support members and braces could be modified in order to minimize trashrack head loss.
- (f) Completed.
- (g) The project ascertained that structural members in trashracks were responsible for the majority of the head (92%). In the past the head loss was calculated assuming that the rack bars were the major cause of loss, and doubling or tripling this estimated loss to allow for support and brace members and partial clogging. The investigation of streamlining of some support members and elimination of others indicated that total trashrack head could be reduced by 70%.
- (h) "Evaluation of Trashrack Design Criteria for Units 8-11 of Rocky Reach Dam," J. F. Orsborn, Research Rept. No. 69/9-50, Coll. of Engr. Research Div., Washington State Univ., May 1969.
- (7766)
ROCKY REACH DAM FOREBAY MODEL AND TRASHRACK MODEL.
- (b) Public Utility District No. 1 of Chelan County, Washington.
- (d) Theoretical and experimental; applied research for design and development.
- (e) The project consisted of model investigations of forebay and powerhouse intake flow conditions in the vicinity of new turbine units to be installed in a presently existing dam on the Columbia River. After the flow direction in vicinity of the trashrack was established, additional model tests were run to compare flow conditions, head loss, and drag on conventionally designed and modified trashracks and rack components.
- (g) The model tests ascertained that the flow condition in the model was generally acceptable. The trashrack study showed that modification of structural support and brace members reduced the total trashrack head loss significantly.
- (7767)
EFFECTS OF TURBULENCE ON DRAG OF ANGULAR BLUNT BODIES.
- (b) National Science Foundation.
- (c) John A. Roberson, Civil Engrg. Prof.
- (d) Experimental and theoretical; basic research for Ph.D. thesis.
- (e) To investigate the effect of turbulence intensity in relation to the coefficient of drag of blunt angular bodies.
- (g) While it is generally felt that turbulence intensity has negligible influence on the coefficient of drag of blunt angular bodies, experimental work indicates an effect. High turbulence in the approach flow has been observed to cause a reduction in the coefficient of drag by 20% or more.
- (7768)
VANCOUVER LAKE HYDRAULIC MODEL STUDY.
- (b) Federal Water Pollution Control Admin.
- (c) Claud C. Lomax, Hydraulic Engineer.
- (d) Experimental; theoretical; field investigation; applied research.
- (e) Hydraulic model study of the lake and possible flushing proposals in order to predict future water quality.
- (7769)
VANCOUVER LAKE HYDROLOGIC AND HYDROGRAPHIC STUDY.
- (b) Port of Vancouver, Washington.
- (c) Alan C. Meyers, Asst. Hydrologist.
- (d) Field investigation; applied research.
- (e) Field instrumentation is being used to observe flow and ecological implications in a tidal estuary and its watershed.
- (7770)
FLOOD ALLOCATION CRITERIA.
- (b) State of Washington, Dept. of Water Resources.
- (d) Field investigation; development.
- (f) Completed.
- (g) The project report presented economic and engineering guidelines and recommendations to be used in improving the efficiency of activities in flood damage reduction.
- (h) In preparation for publication.
-
- UNIVERSITY OF WASHINGTON, Department of Civil Engineering, Seattle, Washington 98105. Professor R. G. Hennes, Department Chairman.
- (6149)
REFLECTED WAVES IN LAKE WASHINGTON.
- (b) Washington State Highway Commission, Olympia, Washington; and Federal Highway Administration.
- (c) Prof. E. P. Richey.
- (d) A field investigation with some theoretical background for the field measurements; applied research.
- (e) Some field data were obtained on the excursion and decay of wind-waves in the deep-water category after they reflected from a vertical wall, with the objective to determine what areas of the lake might be influenced by the reflected waves.
- (f) Completed.
- (h) "Upwind Travel of Reflected Waves," E. P. Richey, Proc. Eleventh Conf. Coastal Engrg., ASCE, Vol. 1, pp. 213-236, 1968.
- (6150)
ATTENUATION OF DEEP-WATER WAVES.
- (b) Washington State Highway Commission, Olympia, Washington.
- (c) Profs. E. P. Richey and R. E. Nece.
- (d) Experimental and theoretical applied research for master's theses.
- (e) Experimental and theoretical investigation of the relative efficiencies of hydraulic, pneumatic and fixed structural devices to minimize the energy of the reflected waves.
- (f) Completed.
- (h) "Dissipation of Deep-Water Waves by Hydraulic

Breakwaters," R. E. Nece, E. P. Richey, V. Rao, Proc. Eleventh Conf. Coastal Engrg., ASCE, Vol. 1, pp. 1032-1048, 1968.

(7771)

ATTENUATION OF DEEP WATER WAVES BY A POROUS-WALLED BREAKWATER.

- (b) Washington State Highway Commission, Olympia, Washington; Federal Highway Administration.
- (c) Prof. E. P. Richey.
- (d) Experimental and theoretical applied research.
- (e) Theoretical and experimental treatment of the attenuating effect of a porous-walled breakwater as a function of wave and breakwater dimensions.
- (f) Completed.
- (h) "Attenuation of Deep Water Waves by a Porous-Walled Breakwater," E. P. Richey and C. K. Sollitt, Proc. Civil Engineering in the Oceans, II, (in print).

(7772)

INTERNAL CURRENTS RESULTING FROM INTERMEDIATE DENSITY INFLOWS INTO STRATIFIED RESERVOIRS.

- (b) State of Washington Water Research Center.
- (c) R. E. Nece, Director, Harris Hydraulics Laboratory.
- (d) Experimental; basic and applied research.
- (e) A laboratory study to study the internal currents established by the inflow of intermediate density into a density-stratified reservoir.

(7773)

GROUNDWATER SEEPAGE PAST SHARP AND ROUNDED CORNERS.

- (b) State of Washington Water Research Center.
- (c) Prof. B. W. Hunt.
- (d) Experimental; basic research.
- (e) The streamline pattern and pressure distribution in the vicinity of a sharp, 270-degree corner is to be investigated experimentally, and then the effect of gradually rounding this corner will be studied. Darcy solutions, obtained with the aid of an electrical analogy, will be compared to the experimental results.

(7774)

UNSTEADY, UNCONFINED SEEPAGE TO A PARTIALLY PENETRATING WELL.

- (c) Prof. B. W. Hunt.
- (d) Theoretical; basic and applied research.
- (e) A linearized, first order solution is being sought for the unsteady, unconfined seepage to a partially penetrating well in an infinitely deep aquifer.

UNIVERSITY OF WASHINGTON, College of Fisheries, Fisheries Research Institute, Seattle, Washington 98105. Robert L. Burgner, Institute Director.

(050W)

DETERMINATION OF INFLUENCE OF WATER QUALITY ON SALMON IN THE DUWAMISH ESTUARY.

- For summary, see Water Resources Research Catalog, Vol. 2, 5.1142.
- (h) "Final Report Estuarine Ecology June 1, 1965-September 30, 1968," Anon. Univ. Wash., Fish. Res. Inst., Seattle, Wash., 80 pp., 1969. "Analysis and Evaluation of Data Obtained from Automatic Water Quality Monitoring Stations on the Duwamish Estuary," William H. Lenarz, Ph.D. thesis, Univ. Wash., Seattle, Wash., 188 pp., 1969. "Estimates of Population Parameters of the 1965 and 1966 Adult Chinook Salmon Runs in the Green-Duwanish River," Gary Dean Stauffer, M.S. thesis,

Univ. Wash., Seattle, Wash., 155 pp., 1969.

(148W)

ESTUARINE ECOLOGY.

- For summary, see Water Resources Research Catalog, Vol. 4, 6.0620.

(149W)

ECOLOGICAL STUDIES OF SALMON AND TROUT AT BIG BEEF CREEK.

- For summary, see Water Resources Research Catalog, Vol. 4, 6.0629.

(6834)

CHUM SALMON SPAWNING CHANNEL.

- (b) U.S. Bureau of Commercial Fisheries (Anadromous Fish Act funds).
- (c) Dr. E. O. Salo and K. V. Koski.
- (d) Experimental field investigation; applied and basic research; one Ph.D. thesis project being supported.
- (e) An artificial spawning channel for experimental manipulation of environmental and biological factors has been built at the University of Washington field station on Big Beef Creek, Hood Canal. Success of chum salmon fry production and fry quality is being measured in relation to flow, intra-gravel water quality, gravel composition, and spawner density in the natural and controlled environments.
- (g) Channel construction has been completed. The second year of information on fry production and fry quality is presently being collected.
- (h) Brief summary of work may be obtained in 1968 and 1969 copies of Research in Fisheries, College of Fisheries, Univ. of Wash., Seattle.

UNIVERSITY OF WASHINGTON, Department of Oceanography, Seattle, Washington 98105. Dr. Maurice Ratray, Jr., Department Chairman.

(6282)

ESTUARINE CIRCULATION STUDIES.

- (b) National Science Foundation.
- (d) Experimental, theoretical and field investigations; basic research which includes thesis problems.
- (e) A completed study on the dynamics of estuarine circulations with physical behavior of any estuarine system.

(7775)

FIELD INVESTIGATION OF BOUNDARY - LAYER FLOW AND SEDIMENT TRANSPORT IN THE SHALLOW MARINE ENVIRONMENT.

- (b) National Science Foundation.
- (c) Asst. Prof. Richard W. Sternberg.
- (d) Field investigation; basic and applied research.
- (e) Measurement of the frictional interaction between the fluid flow and different bed configurations, as well as the threshold of grain motion and mass transport of sediment resulting from boundary currents. The ultimate goal is to predict the occurrence and quantity of sediment transport from a single velocity measurement made near the sea floor.
- (g) Determined drag coefficients associated with various bed configurations. Constructed competence curves for initial motion of sediment grains as a function of velocity, boundary shear stress, and other criterion. Investigated various bedload equations to predict mass transport of sediment under natural marine conditions.

- (h) "Friction Factors in Tidal Channels with Differing Bed Roughness," R. W. Sternberg, Marine Geology, Vol. 6, No. 3, pp. 243-260, 1968.
- "Bedload Transport of Sediment in Ripples During a Tidal Current Flow," R. W. Sternberg and Nancy C. Brandeberry, Amer. Geophys. Union, Pacific Northwest Regional Meeting, Portland (Abstract), 1969.
- "Field Measurements of the Hydrodynamic Roughness of the Deep-Sea Boundary," R. W. Sternberg, Deep-Sea Research. (In Press).
- "Measurements of Incipient Motion of Sediment Particles in the Marine Environment," R. W. Sternberg, Limnology and Oceanography (submitted).
- (7776)
SYNOPTIC MEASUREMENTS OF CURRENTS AND SEDIMENT TRANSPORT ON THE CONTINENTAL SHELF.
- (b) Atomic Energy Commission.
- (c) Asst. Prof. Richard W. Sternberg.
- (d) Experimental; basic research.
- (e) An investigation of bottom currents and associated sediment transport on the continental shelf. An instrument has been designed to rest on the sea floor and measure bottom currents and pressure fluctuations continuously for 30 days, as well as to photograph the bed every half hour for the same period. Data collection begins winter 1971.
- (7777)
A FIELD INVESTIGATION OF TIDAL AND RIVER FLOW OVER NON-UNIFORM BOUNDARIES.
- (b) National Science Foundation.
- (c) Asst. Prof. J. Dungan Smith.
- (d) Theoretical and field investigations; basic research.
- (e) To develop relationships between the local boundary shear stress and velocity field and the shape of the boundary and mean pressure gradient. Instrumentation includes a Preston tube and current-meter array.
- (h) "Boundary Shear Stress in Rivers and Estuaries," J. D. Smith and R. E. Nece, ASCE, J. Waterways and Harbors Div., May 1970 (in press).
- (7778)
ARCTIC BOUNDARY LAYER STUDIES.
- (b) Office of Naval Research.
- (c) Asst. Prof. J. Dungan Smith.
- (d) Field investigations; basic research.
- (e) To determine the coupling between the ice sheet and water beneath and to outline the mechanics of the friction boundary layer. Effects of both form drag and skin friction are being investigated, and detailed measurements are being made of the turbulent and mean flow fields.
- (7779)
SHEAR FLOW EFFECTS IN CONSTANT DENSITY AND STRATIFIED FLUIDS.
- (b) Mechanics Division, Air Force Office of Scientific Research.
- (c) Assoc. Prof. William O. Criminale, Jr.
- (d) Theoretical; basic research.
- (e) Studies include interaction of shear flow and internal waves; nonlinear development of waves in a two-fluid situation; initial value problems at the thermocline; sea-surface dynamics; turbulence in stratified media; formation and development of wakes.
- (g) Linearized analysis for all of the above (e).
- (7780)
INTERNAL WAVES STUDIES.
- (b) National Science Foundation; Office of Naval Res.
- (c) Prof. M. Rattray, Jr.; L. H. Larsen, Res. Asst. Prof.; S. Martin, Res. Asst. Professor.
- (d) Experimental, theoretical, and field investigations; basic research.
- (e) Studies of wave generation, propagation, and interactions; in situ observations of internal waves in the ocean.
- (h) "Internal Waves and Their Role in Mixing The Upper Layers of the Ocean," L. H. Larsen, The Trend in Engineering, Vol. 21, No. 4, 1969, pp. 8-11, 19.
- "Generation of Long Internal Waves at the Continental Slope," M. Rattray, Jr., J. G. Dworski and P. E. Kovala, Deep-Sea Research, Supplement to Vol. 16, 1969, pp. 179-195.
- "Oscillations of a Neutrally Buoyant Sphere in a Stratified Fluid," L. H. Larsen, Deep-Sea Research, Vol. 16, 1969, pp. 587-603.
- "Internal Waves Incident Upon a Knife Edge Barrier," L. H. Larsen, Deep-Sea Research, Vol. 16, 1969, pp. 411-419.
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- WEBB INSTITUTE OF NAVAL ARCHITECTURE, Crescent Beach Road, Glen Cove, New York 11542. Edward V. Lewis, Director of Research.
- (5202)
DETERMINATION OF SHIP WAVE RESISTANCE.
- (b) Naval Ship Research and Development Center.
- (c) Dr. Lawrence W. Ward, Prof. of Engrg.
- (d) Experimental and theoretical; basic research.
- (e) Investigation of means for direct experimental determination of ship wave resistance from measurements of the wave pattern during a model test. Purpose includes improvement in scaling model test results to full size as well as basic understanding of nature of ship resistance.
- (f) Completed.
- (g) Method utilizing forces exerted by the wave pattern on a long vertical cylinder has been developed and tests run. Results are encouraging and in agreement with other investigators. New method utilizing wave slope records has been investigated and found promising.
- (h) "An Assessment of Some Experimental Methods for Determining the Wavemaking Characteristics of a Ship Form," K. W. H. Eggers, S. D. Sharma, and L. W. Ward, Trans. Soc. Naval Arch. and Marine Engrs., 1967.
- "Experimental Determination of Wave Resistance of a Ship Model from Lateral Wave-Slope Measurements," L. W. Ward, Webb Institute, June 1968.
- "Forces Due to Gravity Wave Waves on a Long Vertical Circular Cylinder," L. W. Ward and Joel D. Snyder III, Webb Institute Report, June 1968.
- (5203)
ASSESSMENT OF SEAKEEPING CHARACTERISTICS OF SHIPS.
- (b) Society of Naval Architects and Marine Engrs., Panel H-7 of Hydrodynamics Committee.
- (c) Prof. Edward V. Lewis, Res. Prof. of Naval Architecture.
- (d) Theoretical application of available experimental results and confirmation by model tests; applied research.
- (e) Application of available knowledge of ship model behavior in regular waves to the prediction of trends of ship performance in realistic irregular wave patterns. Experimental confirmation by means of model tests in waves. Purpose is to provide the ship designer with guidance in the selection of hull characteristics.
- (f) Completed.
- (g) The advantage of a high length/draft ratio in

permitting higher speeds before shipping water forward is clearly shown. A corresponding disadvantage in terms of likelihood of slamming is found, requiring a balance to be made in selecting optimum ship characteristics. Fair agreement was obtained between model tests and predictions.

(h) "Assessment of Seakeepability," Norman Hamlin and Roger Compton, Marine Technology, Oct. 1966.

"Ship Model Study of Incidence of Shipping Water Forward," D. Hoffman and W. M. Maclean, Marine Technology, April 1970.

(5942)

MODEL STUDIES OF SHIP SLAMMING IN WAVES.

- (b) American Bureau of Shipping.
- (c) Dr. Walter Maclean, Prof. of Engrg.
- (d) Experimental study making use of ship models in waves; applied research.
- (e) Two 5-foot models, jointed at amidships for measurement of wave bending moments, were run in waves to determine the conditions for bottom slamming to occur and to compare with theoretical predictions. Relative vertical motion and wave slope along keel were measured. Pressure measurements at one point on bottom were taken.
- (g) Fairly good correlation has been obtained between relative vertical velocity at the bow and the occurrence of slamming. However, better correlation is expected when velocity is measured at a point further aft.
- (h) "Further Model Tests for the Investigation of Slamming," W. Maclean, Progress Report No. 11, June 1967. Final report in preparation.

(7781)

EXPERIMENTAL DETERMINATION OF SHIP WAVE RESISTANCE IN MODEL AND FULL SCALE.

- (b) National Science Foundation (Engineering Mechanics Program).
- (c) Dr. Lawrence W. Ward, Prof. of Engrg.
- (d) Experimental and theoretical basic research.
- (e) Development of methods of direct experimental determination of model or ship wave resistance by measurement of the wave pattern, thereby investigating the problems of optimizing hull forms, improving model to full-scale correlation, and devising a technique for determining full-scale ship wave resistance. Includes theoretical work, experimental work in a model tank, and full-scale tests on a boat off the Webb beach. The project has value in providing a hydrodynamic tool of general scientific interest, a method of understanding better the fundamentals of ship resistance, and a means for furthering graduate and undergraduate education.
- (g) Preliminary results include establishment of the assumption of linear superposition of waves, which is basic to all optimization programs, in the special case of fitting a bulb on a trawler hull.
- (h) "Current Activities at Webb Institute in the Area of Wave Resistance Research," Lawrence W. Ward, 12th Intl. Towing Tank Cong., Rome, Italy, Sept. 1969.
- "Investigation of the Use of Signal Averaging to Eliminate the Effect of the Ambient Sea in the Determination of a Ship's Wave Resistance in the Open Ocean," Joel D. Snyder III, Webb Institute thesis, May 1968, also presented at Hampton Roads Section. Soc. Naval Arch. and Marine Engrs., Newport News, Virginia, Dec. 1969.

UNIVERSITY OF WISCONSIN, College of Engineering, Department of Civil Engineering, Madison, Wisconsin 53706. Professor Arno T. Lenz, Department Chairman.

(3539)

MEASUREMENT OF LIQUID VELOCITY AND TURBULENCE.

- (b) Office of Water Resources Research, U.S. Dept. of the Interior.
- (c) Dr. J. R. Villemonte.
- (d) Theoretical and experimental; basic and applied research for M.S. and Ph.D. theses.
- (e) A three-element probe has been developed to permit the simultaneous observation of two components of the instantaneous near-point velocities in liquid flow in closed ducts using an application of the principle of electro-magnetic induction. Reynolds stresses are computed as well as time and space correlations and resulting energy spectra.
- (h) "Characteristics of Liquid Turbulence in Circular Pipes as Measured by a MHD Probe," R. L. Gratz and J. R. Villemonte, ASCE Meeting on Environmental Engineering, Chattanooga, Tenn., 1968.
- "Acquisition and Analysis of Turbulent Water Velocities," R. L. Gratz and J. R. Villemonte, ASCE Hydraulics Div. Specialty Conf., Logan, Utah, 1969.

(4736)

UNSTEADY FLOW IN POROUS MEDIA.

- (b) Office of Water Resources Research; Wisconsin Alumni Research Foundation; and National Science Foundation.
- (c) Dr. P. L. Monkmeier.
- (d) Theoretical and experimental; basic and applied research for Ph.D. theses and M.S. projects.
- (e) The following problems in unsteady flow through a porous medium are under investigation; use of sound waves to determine permeability; effect of stream bank clogging on unsteady flow of ground water; unconfined, unsteady flow of groundwater toward a surface stream.
- (g) A theory, predicting the behavior of sound waves transmitted through an air-saturated porous medium has been developed and verified experimentally. Field data have been used to confirm a new theory which describes the effect of a clogged streambank on the flow of groundwater toward a surface stream. The Dupuit-Forchheimer equation for unsteady unconfined radial flow toward a well has been solved by numerical means and the results prepared in the form of type curves.
- (h) "Unsteady, Unconfined Groundwater Flow Toward A Well," P. L. Monkmeier and W. A. Murray, presented at ASCE Irrigation and Drainage Spec. Conf., Phoenix, Nov. 1968.

(5598)

A STUDY OF GRAVITY WAVES AND THEIR DYNAMIC INTERACTION WITH PILE STRUCTURES.

- (b) National Science Foundation-Sea Grant, Wisconsin Alumni Research Foundation, Ford Foundation.
- (c) Dr. P. L. Monkmeier.
- (d) Theoretical and experimental; basic and applied research for Ph.D. thesis.
- (e) The following problems in gravity wave analysis are under study: development of a single formulation for gravity waves of large-amplitude (i.e., nonlinear waves); examination of the pressure forces on, and the dynamic response of piles and pile groups, subjected to deep-water or intermediate depth waves.
- (g) A higher order nonlinear theory for deep-water waves of finite amplitude has been developed.
- (h) "A Higher Order Theory for Deep Water Waves," P. L.

(5790)

DISPERSION AND SALT WATER INTRUSION IN FLOW THROUGH NON-HOMOGENEOUS POROUS MEDIA.

- (b) Wisconsin Water Resources Center.
- (c) Dr. J. A. Hoopes.
- (d) Theoretical description, coupled with experimental confirmation, of the distribution of a conservative pollutant in flow through different patterns of non-homogeneous media is being sought. The purpose of this study is to develop methods for predicting the resulting distribution of a substance introduced into a natural ground water flow. Theoretical and experimental studies of the distribution of salt water in a layered coastal aquifer are under way.
- (g) Solutions for the distribution of a dissolved substance in a one-dimensional flow through layered media in various arrangements have been obtained.

(5791)

CIRCULATION AND MIXING PROCESSES IN LAKES.

- (b) Wisconsin Water Resources Center.
- (c) Dr. R. A. Ragotzkie, Dr. J. A. Hoopes, University of Wisconsin.
- (d) Theoretical, experimental, and field; basic research for M.S. and Ph.D. theses.
- (e) This investigation deals with field and laboratory model studies of the current and temperature profiles of Lake Superior. These studies are being integrated with mathematical models in an effort to understand and predict motions within the lake and the resulting distribution of substances introduced at various points in the lake.
- (g) Both frictional and frictionless mathematical models of the large-scale circulation in the Great Lakes (currents and internal waves) have been obtained and compared with observations. A small-scale rotating model of Lake Superior has been constructed.
- (h) "Large-Scale Motion in the Great Lakes," G. T. Csanady, J. Geophys. Res., Vol. 72, No. 16, pp. 4151-4162, Aug. 15, 1967.

(6620)

TURBULENCE IN JETS AND STRATIFIED FLOWS.

- (b) Wisconsin Water Resources Center.
- (c) Dr. John A. Hoopes and Dr. H. H. Lettau.
- (d) Theoretical and experimental; basic research for Ph.D. thesis.
- (e) Theoretical expressions for the mean and turbulent velocity fields for a two-dimensional submerged jet are being developed and tested for a two-dimensional water jet. Velocities are determined using an electro-magnetic probe (see project 3539).

(6621)

INFLUENCE OF TURBULENCE ON OIL-WATER SEPARATION.

- (b) American Petroleum Institute.
- (c) Dr. John A. Hoopes, Dr. L. B. Polkowski, and Dr. W. C. Boyle.
- (d) Theoretical and experimental; basic research for M.S. and Ph.D. thesis.
- (e) The rates of agglomeration and breakup of oil droplets and the equilibrium droplet sizes are being studied theoretically and in the stationary, turbulent flow field between parallel oscillating plates as a function of droplet concentration and turbulence level. The purpose of this study is to improve secondary oil recovery in oil refinery, waste water, separation basins.
- (f) Suspended.

- (g) Ph.D. thesis completed in which theoretical models of the turbulent structure in oscillating Couette flows were developed and compared with experimental derivations.

(6622)

INDUCED CIRCULATIONS AND DISSIPATION OF HEAT FROM CONDENSOR COOLING WATER DISCHARGE.

- (b) Madison Gas and Electric Company, Madison, Wisconsin.
- (c) Dr. John A. Hoopes.
- (d) Theoretical, experimental and field; basic and applied research for Ph.D. thesis.
- (e) This is a study of the heat transfer between jets of warm water, discharged horizontally at the edge of Lake Monona by the Company's cooling water outfalls, and the surrounding lake and atmosphere. The investigation involves field measurements of the velocity and temperature patterns induced by the jets throughout the year, mathematical models of the phenomena, and a laboratory model. The purpose of this study is to define the region of the lake affected by the heat and to consider alternate methods of discharging the warm water to reduce this region.
- (f) Completed.
- (g) A mathematical model has been developed which describes the induced circulations and the dilution of the heat by the lake. The model describes the field measurements.
- (h) A Ph.D. thesis has been completed on the mathematical modelling and field studies; an M.S. thesis has been completed on the laboratory modelling. Both are being prepared for publication.

(6623)

DISTURBED LAMINAR FLOW DUE TO PIPE FITTING AND BRANCHES.

- (c) Dr. J. W. Villemonte.
- (d) Experimental; applied research for Ph.D. thesis.
- (e) The Reynolds number range is $10^4 < R < 30,000$ in pipes using oil. The disturbance due to standard type pipe fittings and combined and divided flows in branches is being studied. The objective of the program is to develop design criteria which can be used for estimating energy losses due to fittings operating in the laminar flow regime.
- (f) Suspended.
- (g) A type of Moody diagram has been developed for a wide range of pipe fittings and for gate and globe valves which gives the relationship between the fitting friction factor and the Reynolds number for the range given in part (e) above.
- (h) A Ph.D. thesis has been completed and a paper presenting a portion of the results will be presented at the ASCE Water Resources Conference at Phoenix, Arizona, 1971.

(6624)

THERMOCLINE DEVELOPMENT IN LAKES.

- (b) Wisconsin Sea Grant Program.
- (c) Dr. J. A. Hoopes.
- (d) Theoretical; basic research for Ph.D. degree.
- (e) The transient, vertical distribution of temperature in lakes and reservoirs is being studied, using several models for the vertical transport of heat and momentum. The objective of the work is to develop a model for the temperature structure of a lake which describes the location and stability of the thermocline.
- (g) The thermal energy equation has been solved for the vertical temperature distribution due to:
 - (1) a sinusoidal, surface temperature variation;
 - and (2) various surface radiation inputs.

(6625)

THERMALLY INDUCED MIXING AND OVER-TURNING OF STRATIFIED LAKES AND IMPOUNDMENTS.

- (b) Wisconsin Sea Grant Program.
- (c) Dr. John A. Hoopes.
- (d) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
- (e) Two mathematical models, describing the flow pattern and the rate of dilution induced by the discharge of a buoyant plume or jet into a stratified lake, are being investigated and tested in a small circular tank. The purpose of this work is to investigate the feasibility of inducing vertical mixing in stratified lakes through the introduction of warm water (power plant or industrial discharge) at the bottom of a lake. A model for predicting the change in stability due to a heated water input at the bottom has been developed.

(6629)

DYNAMICS OF VISCOUS DENSITY-STRATIFIED FLOW.

- (b) Federal Water Pollution Control Admin.
- (c) Dr. P. L. Monkmeier.
- (d) Theoretical and experimental; basic and applied research for Ph.D. thesis.
- (e) This study is concerned with the two-dimensional flow of a non-diffusive, viscous, density-stratified fluid toward a point sink. The object of the study is the development of expressions for the shape of the expected withdrawal layer and the form of its associated velocity profiles as a function of spatial coordinates, discharge and characteristics of the density-stratified fluid. A laboratory tank has been utilized to test the theoretical expressions. Application of the results of this study to selective withdrawal from surface impoundments for water quality control was considered.
- (g) Theoretical results have been obtained for the case of a point sink located in the lower corner of a semi-infinite, rectangular flow field. Experimental verification has been satisfactory.
- (h) "Withdrawal of a Viscous Density-Stratified Fluid From the Bottom of a Reservoir," Ph.D. thesis, S. G. Walesh, 1969.
"Withdrawal of a Viscous Density-Stratified Fluid From the Bottom of a Reservoir," S. G. Walesh and P. L. Monkmeier, presented at ASCE Water Resources Engrg. Conf., Memphis, Jan. 1970.

(7782)

A SYSTEMS ANALYSIS OF WATER AND NUTRIENT FLOWS IN THE LAKE WINCRA BASIN.

- (b) Wisconsin Water Resources Center.
- (c) Dr. D. D. Huff.
- (d) Theoretical and field investigation; applied research.
- (e) The long-range objective of this research is development of the capability for computer simulation of the cycling and distribution of eutrophic materials.
- (h) "A Study of Nutrient Transport with the Stanford Watershed Model-I. Formulation of the Computer Model," D. D. Huff, D.G. Watts, O.L. Loucks, and M. Teraguchi. Presented at 1969 Natl. Winter Meeting of the Amer. Soc. of Agr. Engrg., preprints available through correspondent.

(7783)

SURFACE WAVE DAMPING BY UNDERWATER TURBULENCE.

- (b) National Science Foundation.
- (c) Theodore Green, Assoc. Prof.
- (d) Experimental; basic research for M.S., Ph.D. theses.
- (e) The damping of capillary-gravity waves due to thermally produced underwater turbulence is being studied experimentally, for various heating rates.

- (g) Preliminary measurements in which the turbulence was generated by an oscillating underwater grid have been completed.

- (h) "The Damping of Surface Waves by Underwater Turbulence," J. E. Paquin, M.S. thesis, U.S. Naval Postgraduate School, 1969.

(7784)

THE MECHANICS OF THERMAL FRONTS.

- (b) National Science Foundation.
- (c) Theodore Green, John Hoopes, and P. L. Monkmeier.
- (d) Experimental, theoretical.
- (e) Thermal plumes and fronts are under investigation. Emphasis is being placed on their small-scale dynamics, and on the thermal plumes associated with cooling-water outfalls of power plants.

UNIVERSITY OF WISCONSIN, Department of Mathematics,
Madison, Wisconsin 53706. Professor Wolfgang R.
Wasow, Chairman.

(7785)

ASYMPTOTIC METHODS FOR FLUID DYNAMICAL PROBLEMS.

- (b) National Science Foundation.
- (c) Professors R. E. Meyer and M. C. Shen.
- (d) Theoretical and basic research.
- (e) Asymptotic methods developed for studying nonlinear wave motions in geophysical fluid flows and spectra of bounded or unbounded water bodies.
- (g) Stationary wave of permanent type with respect to a rotating cylindrical system was discovered in a stratified rotating fluid, and an asymptotic method based upon geometrical optics theory was developed to determine resonance frequencies of two-dimensional channels and cylindrical water bodies. Asymptotic equations governing nonlinear surface waves on a viscous fluid with surface tension in an inclined channel of arbitrary cross section have also been obtained.
- (h) "Spectra of Water Waves in Channels and Around Islands," M. C. Shen, R. E. Meyer and J. B. Keller, Phys. Fluids, Vol. 11, 2289-2304, 1968.
"Stationary Nonlinear Waves in a Stratified Fluid with Respect to a Rotating Cylindrical System," M. C. Shen, Phys. Fluids, Vol. 12, 1961-1967, 1969.

WOODS HOLE OCEANOGRAPHIC INSTITUTION, Woods Hole,
Massachusetts 02543. Dr. Paul M. Fye, Director.

(7786)

DYNAMIC PROCESSES IN THE DEEP SEA.

- (b) Office of Naval Research.
- (c) Dr. N. P. Fofonoff.
- (d) Theoretical and field investigations.
- (e) Time series observations in the deep ocean, and theoretical studies are used in the determination of the nature of dynamic processes in the sea.
- (h) "Spectral Characteristics of Internal Waves in the Ocean," N. P. Fofonoff, Deep-Sea Research, 1969, Supplement to Vol. 16, pp. 59-71.

(7787)

GULF STREAM STUDIES.

- (b) Office of Naval Research.
- (c) Mr. F. C. Fuglister.
- (d) Theoretical and field investigations.
- (e) To investigate the three-dimensional time-dependent Gulf Stream system in the region east and north of Cape Hatteras, and to relate the conditions and changes of the Gulf Stream to the

- larger problems of circulation and variability of the North Atlantic Basin.
- (g) Studies have resulted in the knowledge of the presence of high velocities in a relatively narrow band over the entire downstream path; the meandering of the path; and the formation and dissipation of rings from the Gulf Stream.
- (h) "Cyclonic Rings Formed by the Gulf Stream 1965-66," F. C. Fuglister. This paper is to be part of the *Geog Wüst 80th Birthday Volume* (June 15, 1970), publisher not yet designated.
- (7788)
A SURVEY OF THE DEEP WESTERN BOUNDARY CURRENT OF THE SOUTH PACIFIC.
(b) National Science Foundation.
(c) Dr. B. A. Warren.
(d) Basic research.
(e) To study deep circulation from the Antarctic to the Pacific particularly in relation to the prediction that Antarctic water flows northward as a narrow current along the western boundary of the deep South Pacific.
- (f) The observational work has been completed but the program continues to be active in the analysis of data and the study of the basic postulation.
- (g) Preliminary studies indicate existence of the narrow current as predicted by circulation theory.
- (h) "General Comments on the Circulation of the South Pacific," to be published by the U.S. Nat. Acad. of Sci. in "Scientific Exploration of the South Pacific."
- "Eltanin Cruise 40," to be published (1970) in "Antarctic Journal of the United States," 5, 4.
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- WORCESTER POLYTECHNIC INSTITUTE, Alden Research Laboratories, Worcester, Massachusetts 01609. Professor Lawrence C. Neale, Director, Research Laboratories.
- (1963)
METER CALIBRATIONS.
(b) Foxboro.
(d) Experimental, for design.
(e) Calibration of various sizes of magnetic flow tubes (1" to 36" diameter) and a variety of nozzle and orifice plate assemblies.
(f) Tests in progress.
- (3859)
METER CALIBRATIONS.
(b) B-I-F Industries, Providence, R. I.
(d) Experimental, for design.
(e) Calibration of open flow nozzles and flow tubes up to 48" in diameter. Tests performed in standard test loop and also in mock-up of particular field installations.
(f) Tests in progress.
- (4255)
METER CALIBRATIONS.
(b) Badger Meter Company, Milwaukee, Wisconsin.
(d) Experimental; for design.
(e) Calibration of open flow nozzles and flow tubes from 2" to 48" in diameter in the standard test loop. In addition, tests have been performed to determine operating characteristics in a variety of field installation mock-ups including a number of pipe surface finishes.
(f) Tests in progress.
- (4746)
METER CALIBRATIONS.
(b) Hagan Chemicals and Controls, Inc., Pittsburgh, Pa.
- (d) Experimental, for design.
(e) Calibration of a variety of sizes and designs of flow nozzles and flow nozzle assemblies.
(f) Tests in progress.
- (5279)
METER CALIBRATIONS.
(b) ITT General Controls, Warwick, R. I.
(d) Experimental, for design.
(e) Calibration of flow tubes in a range of sizes from 6" to 48" has been carried out. Field piping as well as standard test loop installation have been used.
- (5962)
METER CALIBRATIONS.
(b) Bailey Meter Company, Wickliffe, Ohio.
(d) Experimental, for design.
(e) Calibration of flow nozzles and flow meters in standard as well as particular metering and piping configurations for a range of sizes from 1" to 16" diameter.
- (5963)
METER CALIBRATIONS.
(b) Fischer and Porter Company.
(d) Experimental for design.
(e) Calibration of various sizes of magnetic flow tubes from 2" to 48" diameter.
- (5971)
WILLOW GLEN STEAM POWER PLANT.
(b) Stone and Webster Engineering Corp.
(d) Experimental for design.
(e) A 1/12 scale model of the proposed circulating water pump intake has been constructed for the Gulf State Utility Company. The model studies are to evaluate the alternative designs for the intake and water passages. Velocities and flow distribution will be measured and other critical phenomena near the pump inlets will be observed.
(f) Tests completed. Report in file.
- (6499)
NORTHFIELD PUMPED STORAGE DEVELOPMENT.
(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/200 horizontal by 1/60 vertical scale model of the section of the Connecticut River between Vernon Dam and Turners Falls was constructed for the Northeast Utilities Corporation. The model included provision to reproduce both pumping and generating plants at the Northfield Power Plant as well as river flows at Vernon, Ashuelot River, Millers River and Turners Falls. Studies involve the effect of various modes of plant operation on the river and the other plants.
(f) Tests completed. Report in preparation.
- (6500)
NORTHFIELD PUMPED STORAGE DEVELOPMENT.
(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/46 scale model of the intake at the upper reservoir was constructed for Northeast Utilities, Inc. Included in the model was a section of the reservoir, the intake and a section of the penstock below the intake. The purpose was to study the flow patterns in the model during various phases of operation and to develop the structures and excavations in such a way to optimize the operation for both pumping and generating conditions.
(f) Tests completed. Report in file.

(6501)

NORTHFIELD PUMPED STORAGE DEVELOPMENT.

- (b) Stone and Webster Engineering Corp., Boston, Mass.
- (d) Experimental, for design.
- (e) A 1/25 scale model of a section of the tunnel and penstocks was fabricated in steel and plastic for the Northeast Utilities, Inc. The model was comprised of a section of the large tunnel, the 46 vertical bend, the bifurcation and sections of the two penstocks beyond the bifurcation. The model was arranged to measure pressures at all critical sections as well as velocity profiles, and windows of clear plastic were installed to permit photographs in the different sections. The study is concerned with determination of the loss coefficient for the various changes in section and alignment and with the minimizing of pressure fluctuations produced by different combinations of flow in the model.

(f) Tests completed. Report in file.

(6502)

BIG BEND POWER STATION.

- (b) Stone and Webster Engineering Corp., Boston, Mass.
- (d) Experimental, for design.
- (e) A 1/19 scale model of the discharge channel for condenser cooling water including the outlet and transition structure for the flow from Unit No. 1 was constructed for Tampa Electric Company. The model channel was formed in concrete and the structure in wood and steel. The flow from future units can be introduced through the upper end of the channel. The study involved developing a system of baffles and transitions to produce a uniform velocity into the channel from the unit such that no scour or erosion of side slopes would result.

(f) Tests completed. Report in file.

(6503)

H. B. ROBINSON POWER PLANT.

- (b) Ebasco Services, Inc., New York City.
- (d) Experimental, for design.
- (e) A 1/10 scale model of the transition and outlet works for the cooling water from the plant is being constructed for the Carolina Light and Power Company. The model is constructed of plastic and steel for the pipe and transition sections and wood and concrete in the areas involving topography of the natural river bed. The model will be a sectional model with the split on the centerline replaced with a sheet of clear plastic to permit observation of flow through the model. The study is designed to allow measurement of velocities at several sections including the exit to insure a uniform distribution at the release to the natural bed.

(f) Tests completed. Report in file.

(6504)

WEBSTER STEAM ELECTRIC STATION.

- (b) Ebasco Services, Inc., New York City.
- (d) Experimental, for design.
- (e) A 1/12.75 scale model of a section of a cooling water discharge canal was constructed for the Houston Lighting and Power Company. The model included the intake and intake drop structure, and a section of the canal downstream. The study involved evaluating the loss coefficients for the various parts of the model and installing and testing modifications aimed at reducing the head losses in the canal.

(f) Tests completed. Report in file.

(6505)

PILGRIM NUCLEAR POWER PLANT.

- (b) Bechtel Corporation, San Francisco, Calif.
- (d) Experimental, for design.
- (e) A 1/50 scale model of a section of Massachusetts Bay near the Boston Edison Company plant was constructed to evaluate storm protection at the proposed plant. A 4000 ft. section of the shore line and the bay for an equal distance off shore were reproduced including the plant cooling water inlet and outlet structures. A 40-ft. long variable speed and variable stroke wave maker was installed to generate the storm driven waves. Electronic probes were installed at critical locations to measure and record wave heights and frequencies. A variety of breakwater configurations and combinations are being tested as part of the program.

(f) Tests completed. Report in preparation.

(6506)

CAYUGA STEAM POWER PLANT.

- (b) Sargent and Lundy Engineers, Chicago, Ill.
- (d) Experimental, for design.
- (e) A distorted model with scales of 1/150 horizontal and 1/20 vertical has been constructed for the Public Service of Indiana of a 2-1/2 mile section of the Wabash River at the site of the power plant. The model includes sections from 4500 ft. upstream of the cooling water intake and 1500 ft. downstream of the intake and 1500 ft. upstream of the outlet and 4500 ft. downstream of the outlet.

(f) Tests completed. Report in file.

(6507)

CAYUGA STEAM POWER PLANT.

- (b) Foster Wheeler Company.
- (d) Experimental, for design.
- (e) A 1/10.8 scale model of one pump well from section in river through racks and screens to include pump area has been constructed of the Cayuga Steam Power Plant of the Public Service of Indiana. The studies are designed to optimize the pump well arrangement and to determine the flow patterns throughout the structure. The main pump flow is modeled by a siphon passive-type of flow system.

(f) Tests completed. Report in file.

(6508)

POINT BEACH NUCLEAR PLANT.

- (b) Sargent and Lundy Engineers.
- (d) Experimental, for design.
- (e) A 1/14 scale model of the pump well structure has been fabricated for the Wisconsin Michigan Power Company. The model includes the intake pipes, butterfly valves, pump wells and siphon passive-type main pumps. The model is of steel and plexiglass with the pump bells modeled in fiberglass. The purpose is to study the flow patterns in the well and to develop a uniform distribution of flow through the screens and to the main pumps.

(f) Tests completed. Report in file.

(6509)

INDIAN POINT STEAM PLANT.

- (b) Consolidated Edison Company, New York.
- (d) Experimental, for design.
- (e) A 1/250 horizontal by 1/60 vertical scale model of a section of the Hudson River is being constructed for the Consolidated Edison Company. A 4.5 mile section of the river including the Indian Point development of units one, two and three will be studied. The model will be operated to reproduce automatically the tide cycle and will be used to study the flow patterns of the heated cooling

water on return to the river. The measurements will include the flows, detailed velocities and temperature profiles over the river.

(f) Tests in progress.

(6510)

CORNWALL PUMPED STORAGE DEVELOPMENT.

(b) Consolidated Edison Company.

(d) Experimental, for design.

(e) A 1/150 horizontal by 1/75 vertical scale model of a section of the Hudson River was modeled including the section at the tailrace of the plant. The studies involved determination of optimum shape of the tailrace and flow patterns and velocities for various phases of plant operation and various tide conditions. Protection of marine life in the river was also studied.

(f) Tests completed.

(h) Model held in readiness for additional studies.

(6512)

JOCASSEE PUMPED STORAGE DEVELOPMENT.

(b) Duke Power Company.

(d) Experimental, for design.

(e) A 1/50 scale model of the upper reservoir was constructed for the Duke Power Company under the guidance of Charles T. Main, Inc. engineers. Included in the model was a section of the reservoir, the two intake structures, and sections of the tunnel beneath each structure. The study involved the interaction of the local topography and the flow into and out of the structures. Measurements of velocity for a variety of configurations were made both outside the structures in the reservoir and within the structures themselves. In addition a cylinder gate was constructed of fiberglass and instrumented with strain gauges to evaluate dynamic forces on the gate during various modes of operation.

(f) Tests completed. Report in file.

(h) Model held in readiness for additional tests.

(6513)

PEACH BOTTOM NUCLEAR STATION.

(b) Philadelphia Electric Company.

(d) Experimental, for design.

(e) A 1/300 horizontal by 1/30 vertical scale model of the section of the Susquehanna River between Holtwood Dam and Conowingo Dam was constructed. In addition to the Holtwood and Conowingo installations the Muddy Run Pumped Storage Plant is included. At the Peach Bottom site a variety of intake and outlet structures will be studied in evaluating the heat effect on the reservoir of the Peach Bottom cooling water. Weekly cycles of plant operation at all four power stations are modeled during a test and temperature measurements at approximately 250 locations are recorded every minute of model operation. The reservoir temperature is varied from 40°F to 85°F and plant increase has been varied from 8°F to 30°F.

(f) Tests completed. Report in preparation.

(6514)

MORGANTOWN STEAM POWER STATION.

(b) Potomac Electric Power Company.

(d) Experimental, for design.

(e) A 1/400 horizontal by 1/40 vertical scale model of a 16-mile section of the Potomac River has been constructed. This model includes the section of the Potomac between Upper Cedar Point and Swan Point and is in the tidal range of the river. The controls are designed to automatically produce the selected tide cycle in the model and

to produce river temperatures from 40°F to 85°F. In addition the incremental temperature is applied to the plant flow and can be varied over a range from 0 to 30°F. The study is being conducted to evaluate the heat effect of the condenser cooling water in the river. Instrumentation has allowed approximately 150 temperature probe locations to record data each minute of operation.

(f) Tests completed. Report in preparation.

(6515)

CALVERT CLIFFS NUCLEAR POWER PLANT.

(b) Baltimore Gas and Electric Company.

(d) Experimental, for design.

(e) A 1/1000 horizontal by 1/100 vertical scale model is being constructed of an 18-mile section of Chesapeake Bay including the plant site. The limits are from a section above Tilghman Island to below Hooper's Island. The model is designed to reproduce the tidal effects that are present in this section of the Bay and will have a water temperature range of from 40°F to 85°F. The cooling water effluent from the model plant will be heated to reproduce the possible temperature in the prototype plant. The purpose of the study is to determine the flow patterns and distribution of the heated effluent in the bay.

(f) Tests completed. Report in preparation.

(6835)

METER CALIBRATIONS.

(b) Ramapo Instruments Company, Bloomingdale, N. J.

(d) Experimental, for design.

(e) Calibration of large type flow meters for application in pipes varying in size from 8" in diameter to 48" in diameter.

(7789)

NORTHFIELD PUMPED STORAGE DEVELOPMENT.

(b) Stone and Webster Engineering Corp., Boston, Mass.

(d) Experimental, for design.

(e) A 1/20 scale model of the intersection of the tailrace tunnel and the surge chamber was constructed to evaluate the performance characteristics of the differential orifice-type surge chamber entrance. The model was instrumented with electronic transducers as well as pressure gauges and manometers to document variations in pressure. A complete 4-quadrant test was conducted with flow measurement in either direction available in each of the three legs.

(f) Tests completed. Report on file.

(7790)

VERMONT YANKEE NUCLEAR POWER PLANT.

(b) Ebasco Services, Inc., New York City.

(d) Experimental, for design.

(e) A 1/12.3 scale model of the intake structure for the condenser cooling water was constructed and studied to determine the flow patterns to the vertical pumps. The pump bells were modeled in fiberglass and the pump flows were generated by a syphon arrangement for a "passive" test. The return flow from the cooling towers was modeled along with the control and intake structure for this flow.

(f) Tests completed. Report in file. Model held in readiness for additional tests.

(7791)

PILGRIM NUCLEAR POWER STATION.

(b) Bechtel Corporation, San Francisco, Calif.

(d) Experimental, for design.

(e) A 1/50 scale model of the bay and shoreline adjacent to the proposed plant of the Boston

- Edison Company was constructed. A moveable wave generator was provided to produce the variety of waves required. Instrumentation included continuous sensing and recording of water surface elevations at a number of locations. Various arrangements of dikes, breakwaters, sea walls, intakes and outlets were tested to optimize the storm protection of the power plant.
- (f) Tests completed. Report in preparation.
- (7792)
GILBOA PUMPED STORAGE PROJECT.
(b) Charles T. Main, Inc.
(d) Experimental, for design.
(e) A 1/75 scale model of the upper reservoir of the Gilboa Project of the Power Authority of the State of New York has been constructed. The study is designed to evaluate the performance of a number of different intake-outlet designs for the reservoir. These structures must insure a smooth flow without vortex formation and provide elimination of floating ice and other debris from the generating flow. Flow-away characteristics and possible scour were studied during the pumping phase.
- (7793)
GILBOA PUMPED STORAGE PROJECT.
(b) Charles T. Main, Inc.
(d) Experimental, for design.
(e) A 1/50 scale model of a section of the lower reservoir has been constructed for the Power Authority of New York. This section includes the spillway stilling basin and several thousand feet of downstream river bed. The study has involved the approach flow to the spillway, the operation of the spillway and stilling basin. Also involved was the distribution of flow and velocity patterns in the river downstream. Finally the spillway radial gates will be calibrated in place.
- (7794)
EASTON NUCLEAR POWER STATION.
(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) A 1/20 scale model of a section of Hudson River near Albany was constructed to include the condenser cooling water intake and outlet for the power station of the Niagara-Mohawk Company. The outlet design incorporated a venturi-submerged structure arranged to minimize the entry of fish. Heated water was supplied to the outlet to allow identification of mixing patterns in the river.
(f) Tests completed. Report on file. Model held in readiness for further studies.
- (7795)
BEAVER VALLEY NUCLEAR POWER STATION.
(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/125 horizontal by 1/25 vertical distorted scale model of a section of the Ohio River at the site of Shippingport and Beaver Valley Station sites of the Duquesne Light Company was constructed and tested. The present Shippingport plant intake and outlet were included in order to monitor any effect on the operating temperatures due to operation of Beaver Valley plant. Warm water properly scaled was used to model both plant flows. Data was obtained by continuous records at 150 locations in the model. Location and type of structure for both intake and outlet of Beaver Valley plant were studied.
(f) Tests completed. Report on file.
(h) Model held in readiness for further tests.
- (7796)
LUDINGTON PUMPED STORAGE PROJECT.
(b) Experimental, for design.
(d) Ebasco Services, Inc., New York City.
(e) A 1/122 scale model of the upper reservoir of the Ludington station of the Consumers Power Company and the Detroit Edison Company was constructed. The model included all the topography within the reservoir as well as the intake structure and a portion of each of the penstocks. The study involved an evaluation of flow patterns in the reservoir during both pumping and generating modes to insure adequate protection of structure and embankments. Also the possibility of unusual flow conditions at the intake was studied for the generating mode. During this same mode head loss measurements in the intake and penstock entrances have been measured.
- (7797)
VERMONT YANKEE NUCLEAR POWER STATION.
(b) Ebasco Services, Inc., New York City.
(d) Experimental, for design.
(e) A 1/10.5 model of the discharge structure including a section of the Connecticut River was constructed. The purpose of the study was to evaluate performance of the structure in accommodating and regulating the flows from and to other sections of the plant. Flows enter the structure at different locations from the condensers and from the cooling towers. Flows leave the structure to the cooling towers, return to the intake and to the river. A wide range of flow rate in each of these parts was the main interest of the studies. Velocity measurements and eddy formation and water surface documentation were involved in the studies.
(f) Tests completed. Report in file. Model held in readiness for further tests.
- (7798)
JAMES A. FITZPATRICK NUCLEAR STATION.
(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/80.1 scale model of section of Lake Ontario adjacent to the Fitzpatrick plant site of the Power Authority of the State of New York was constructed and tested. The model included the intake and outlet for condenser cooling water as well as the influence of the outflow from nearby Nine Mile Point Power Station. The tests involved thermocouple readings to survey the model area and evaluate structural or operating changes. Patterns of elevated temperature water were developed from this type of data.
- (7799)
CALVERT CLIFFS NUCLEAR POWER PLANT.
(b) Foster Wheeler Corporation.
(d) Model pump performance.
(e) A 12-inch model of the main circulating water pumps for the Baltimore Gas and Electric Company's Calvert Cliffs Nuclear Power Plant is being assembled for test to determine its performance characteristics in the ARL 100-HP pump test rig.
(f) Test in progress.
- (7800)
NEW MADRID STEAM PLANT.
(b) Foster Wheeler Corporation.
(d) Model pump performance.
(e) A 12-inch diameter model of the 84-inch VA main circulating water pump for the New Madrid Steam Plant was tested to determine its performance characteristics in the ARL 100-horsepower vertical

pump test rig. The test rig is designed for a flowrate of 10,000 gpm which is measured with a calibrated venturi. The 100-HP direct current motor is mounted on the rig as a driving dynamometer with a selected speed range of 650 to 1600 rpm. Models up to 14 inches in diameter may be tested in this rig. A smaller 40-HP test rig is also available for model tests.

(f) Tests completed.

(7801)

EAGLE MOUNTAIN NO. 3.

(b) Foster Wheeler Corporation.

(d) Model pump performance.

(e) A 12-inch diameter model of the main circulating water pump for the Texas Electric Service Company's Eagle Mountain No. 3 Station was tested to determine its performance characteristics in the ARL 100-HP pump test rig.

(f) Tests in progress.

(7802)

SEABROOK NUCLEAR POWER STATION.

(b) Ebasco Services, Inc., New York City.

(d) Experimental for design.

(e) A 1/28 scale model of the offshore discharge of condenser cooling water and surrounding area at the Seabrook plant site of the Public Service Company of New Hampshire was constructed and studied. The purpose of the study was to analyze the operation of the jet discharge with and without tidal or coastal currents. Data and results developed the dilution characteristics of the jet, disturbances of the water surface at the point of intersection, "flow away" velocities and temperatures and bottom scour along the centerline of the bottom discharge jet. Warm water was used as the jet and data was obtained on temperatures with thermocouples and thermistors while velocities were measured with miniature current meters and hot-wire devices.

(f) Tests completed. Report in file. Model held in readiness for further testing.

(7803)

OYSTER CREEK NUCLEAR POWER STATION.

(b) Burns and Roe, Inc.

(d) Experimental, for design.

(e) A 1/50 scale model of an area surrounding the cooling water outlet of the Oyster Creek Plant of the Jersey Central Power Company was constructed and tested. The basin containing the studies was approximately 30 feet by 40 feet in area. The outlet pipe was modeled and the data taking consisted of temperature and velocity surveys over the basin. Warm water at various temperatures was released through the outlet to simulate various operating conditions.

(f) Tests in progress.

(7804)

WAGNER STEAM POWER PLANT.

(b) Baltimore Gas and Electric Company.

(d) Experimental, for design.

(e) A 1/300 horizontal by 1/20 vertical scale model of a section of Baltimore Harbor including the existing plant site was constructed for the Baltimore Gas and Electric Company. The purpose of the study was to evaluate temperature and flow patterns resulting from the addition of a new generating unit at the plant. The existing intake and outlet system was installed and operated with the prescribed flows and incremental temperatures. A variety of structures and operating conditions for the new unit were tested. The

data and results were developed from surveys of temperature and velocity during various tide conditions.

(f) Tests completed. Report in preparation.

(7805)

MIDLAND NUCLEAR POWER STATION.

(b) Bechtel Corporation, San Francisco, California.

(d) Experimental, for design.

(e) A 1/200 scale model of the cooling pond of the Midland Plant of the Consumers Power Company of Michigan was constructed and tested. The intake and outlet to the pond were included along with the entire dike arrangement. Instrumentation included controls to regulate flow and temperature difference at the structures as well as thermocouples and recorders to survey the pond temperatures. The purpose of the study was to evaluate various baffle arrangements within the pond and to optimize the cooling characteristics by changes in the baffles and in the outlet-inlet structures.

(f) Tests completed. Report in preparation.

WYLE LABORATORIES, Scientific Services and Systems Group, 128 Maryland Street, El Segundo, California 90245. Dr. Kenneth M. Eldred, Vice President and Technical Director.

(7806)

INVESTIGATION OF NOISE GENERATION MECHANISMS OF ROCKET EXHAUSTS.

(b) National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama.

(c) J. E. Robertson, Wyle Laboratories, Research Division, Huntsville, Alabama 35812.

(d) Experimental and theoretical, basic research.

(e) This effort consists of both experimental and theoretical studies of the mean flow, turbulence, and acoustic radiation properties of subsonic and supersonic jet flows. Recent experiments to measure the wave number spectra of subsonic jet turbulence have been performed. A generalized theory for noise radiation by subsonic and supersonic turbulent shear layers has been developed.

(g) Experimental jet turbulence data have been reported which define the overall intensity, power spectra, and noise radiation parameter for various regions of subsonic jets. The jet noise theory has also been reported. Work is continuing in both areas.

UNIVERSITY OF ARKANSAS, Department of Agricultural Engineering, Fayetteville, Arkansas 72701. Professor Billy B. Bryan, Department Head.

(7830)

GROUNDWATER-SURFACE WATER INTEGRATION STUDY IN THE GRAND PRAIRIE REGION OF ARKANSAS.

(b) Arkansas Agricultural Experiment Station (USDA) cooperatively with Water Resources Research Center (USDI).

(c) Dr. Carl L. Griffis, Research Associate.

(d) Basic and applied research.

(e) (1) From collection, compilation, and analysis of current hydrologic and geologic data, to evaluate the projected demand on the ground water resource in the Grand Prairie in comparison with the available supply; (2) quantify the recharge occurring from a selected reach of a natural channel within the Grand Prairie and to investigate the possibility of increasing this recharge. This will be

- accomplished using both laboratory model studies and on-site field evaluation of the most promising methods as indicated by the lab investigations.
- (3) Evaluate this increased recharge in light of objective Number 1 to determine the feasibility of substantially increasing the total ground water resource in the Grand Prairie.
- (g) Analog study of a selected 48-square mile area of the Grand Prairie Quaternary aquifer; and an analog model being developed.
- (h) "Ground Water Levels in Wells in the Grand Prairie and Eastern Arkansas," Kyle Engler, Ark. Agric. Exp. Sta., Arkansas Farm Res., May-June 1965.
- "Hydrology of a Part of the Grand Prairie Region, Arkansas," R. T. Sniegocki, USGS Water Supply Paper 1615-B, 1964, 71 pp.
- "Testing Procedures and Results of Studies of Artificial Recharge in the Grand Prairie Region, Arkansas," R. T. Sniegocki, F. H. Bayley III, Kyle Engler and J. W. Stephens, USGS Water Supply Paper 1615-G, 1965, 56 pp.
- "Laboratory Study of Aquifer Properties and Well Design for an Artificial Recharge Site," A. I. Johnson, R. P. Moston, and S. F. Versaw, USGS Water Supply Paper 1615-H, 1966, 42 pp.
- See 1964 issue, Project No. 2255, for Water Supply Papers 1615-A, C, D, E, F. Water Supply Papers available from Superintendent of Documents, U.S. Govt. Printing Office, Wash. D.C. 20402.

(7831)

SUBSURFACE IRRIGATION RESEARCH IN ARKANSAS.

- (b) Arkansas Agricultural Experiment Station (USDA).
- (d) Experimental, field investigations; basic and applied research.
- (e) An analysis of forming orifices, system-operating pressures, lateral pipe spacing, and system automation for subirrigation.
- (g) (1) A pressure head of 6 ft. of water is preferred to 10 ft.; (2) 38-inch lateral pipe spacing is preferred over 76-inch spacing; (3) an orifice spacing of 30 inches is preferred to a spacing of 12 or 48 inches. It was concluded that the detriment to a completely automated system is the need of a soil moisture-sensing device that does not drift out of calibration and is operable over a wide range of soil-moisture tensions.
- (h) "Subsurface Irrigation Research in Arkansas," John P. Hoskyn and Billy B. Bryan, Water Res. Center Publication No. 3, in cooperation with Agricultural Experiment Station (Ark. Exp. Sta. Report Series 179).

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

CORN BELT BRANCH, 108 Soils Building, University of Minnesota, St. Paul, Minnesota 55101. Dr. C. A. Van Doren, Branch Chief.

(1723)

HYDRAULICS OF WATER CONTROL STRUCTURES AND CHANNELS.

- See St. Anthony Falls Hydraulic Lab. Project Nos. 111, 1168, 2386, and 7677. See also U. S. Dept. of Agriculture, Agricultural Research Service, Soil and Water Conserv. Res. Div., Southern Plains Branch, Project No. 4335 and Illinois State Water Survey Division, Project No. 1865.
- (b) Cooperative with the Minnesota Agric. Expt. Sta.; the St. Anthony Falls Hydraulic Lab.; and the Illinois State Water Survey.
 - (c) Mr. Fred W. Blaisdell, Research Investigations Leader, St. Anthony Falls Hydraulic Lab., 3rd Ave. S. E. at Mississippi River, Minneapolis, Minn. 55414.
 - (d) Experimental; applied research for development and design.
 - (e) Research dealing with the design, construction, and testing of structures for conserving and controlling soil and water are carried out. Cooperation with and coordination of the tests at the Stillwater, Oklahoma, Outdoor Hydraulic Laboratory and the Illinois State Water Survey are maintained.

A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet. The elbow and transition between the two-way drop inlet and the barrel is being studied to determine the pressures and the best form to minimize the possibility of cavitation. The transition between a circular pipe and a rectangular cantilevered outlet has been studied to determine the best form of the transition. Studies are also being conducted on cantilevered outlets.

- (g) If the anti-vortex plate on the two-way drop inlet is too low, undesirable orifice flow will control the discharge. If the anti-vortex plate is too high, harmful vortices will form under the plate. Rules for determining acceptable plate heights have been determined. The overhang of the plate must be greater than a certain minimum to insure satisfactory performance. The action of the two-way drop inlet is that of a self-regulating siphon. The tests using air agree with the results obtained from the water tests and are much easier to perform. Air is used as the model fluid only for the condition of full conduit flow.

To supplement the experiments, potential flow methods have been used to determine the theoretical coefficient of energy loss at the crest of the two-way drop inlet.

Six shapes of elbow between the two-way drop inlet and the transition were tested. The best elbow shape is an ellipse with semi-major and semi-minor axes of 2D and 1D. (D is the barrel diameter.) An elbow made up of two 45-degree circular segments of radii D/2 and 3D/2 also has generally satisfactory hydraulic characteristics.

Seven transitions between the half-square crown -- half-circular invert cross-section at the elbow exit and the circular barrel were tested. The best transition is warped and 1D long.

(Transition details may be found in 1968 issue -- ed.)

The entrance loss coefficients are low and identical within the limits of experimental precision for all elbow-transition combinations. Tests on the hood drop inlet have shown that the hood barrel entrance can be used to reduce the minimum required height of the drop inlet. Minimum sizes of drop inlet and anti-vortex devices have been determined. Tests of low-stage orifices in the two-way drop inlet have shown that improper location and improper proportioning of the orifices can prevent priming of the spillway. The proper location of the orifices and the sizes of the orifices for satisfactory spillway performance have been determined.

When the flow cross-section is changed abruptly from a circular pipe to a rectangular open channel the rectangular channel width must be 1.0D, where D is the pipe diameter, to prevent excessively high waves and disturbances in the rectangular channel. (See 1968 issue for details -- ed.) Although there is a diamond shaped wave pattern with waves of significant height in the 1.0D-wide channel, the transition performance is generally satisfactory at all discharges between $Q/D^{5/2} = 4$ and 20.

- (h) "Crest Losses for Two-Way Drop Inlet," George G. Hebaus, ASCE, J. Hydraulics Div., Vol. 95, No. HY3, pp. 919-940, May 1969.
- "Abrupt Transition from a Circular Pipe to a Rectangular Open Channel," Fred W. Blaisdell, Charles A. Donnelly, and Kesavarao Yalamanchili, St. Anthony Falls Hydraulic Lab. Tech. Paper No. 53, Ser. B., 67 pp., July 1969.

(4271)

AGRICULTURAL DRAINAGE SYSTEMS DESIGN, MATERIALS, INSTALLATION AND MAINTENANCE.

(4275)

MECHANICS AND CONTROL OF SOIL EROSION BY WATER.

- (b) Cooperative with Purdue University Agricultural Expt. Station.
- (c) W. H. Wischmeier and L. D. Meyer, Agr. Eng. Bldg., Purdue U., Lafayette, Ind. 47907.
- (d) Experimental, theoretical, and field investigations; basic, applied and developmental research.
- (e) Field, laboratory, and analytical studies of (1) soil detachment and transport by rainfall and runoff, (2) effects of plant covers, crop residues, tillage methods, and soil treatments on erosion and runoff, (3) hydraulics of eroding runoff and rainfall, (4) mathematical models of the soil erosion process as a basis for improved methods of erosion prediction and erosion control.
- (g) (1) A basic mathematical model of the soil erosion process was developed and field tested, (2) the kinematic overland flow model and a runoff detachment/transport model were successfully used in the erosion model, (3) laboratory data on turbulence, velocity, and depth of overland flow during rainfall were obtained, (4) surface mulch and applied topsoil greatly reduced erosion from denuded construction sites, and (5) mulch rates up to several tons per acre were required to control erosion on steep slopes, but less mulch was adequate on less erodible conditions.
- (h) "Mathematical Simulation of the Process of Soil Erosion by Water," L. D. Meyer and W. H. Wischmeier, Trans. ASAE 12(6):754-758, 762, 1969.
- "Small Amounts of Surface Mulch Reduce Soil Erosion and Runoff Velocity," L. A. Kramer and L. D. Meyer, Trans. ASAE:12(5):639-641, 645, 1969.

"Erosion Equations Predict Land Slope Development," L. D. Meyer and L. A. Kramer, Agricultural Engrg. 50(9):522-523, 1969.

"Simulation of Overland Flow on Short Field Plots," G. R. Foster, L. F. Huggins and L. D. Meyer, AGU Water Resources Res. 4(6):1179-1187, 1968.

"Relation of Soil Properties to Its Erodibility," W. H. Wischmeier and J. V. Manering, Soil Sci. Soc. Amer. Proc. 33(1):131-137, 1969.

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U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

NORTHEAST BRANCH, Plant Industry Station, Beltsville, Maryland 20705. Dr. H. L. Barrows, Branch Chief.

(4283)

PROCESSES OF STREAM CHANNEL DEVELOPMENT IN THE NORTHEAST.

(c) Paul H. Blinco, Research Hydraulic Engr., Dept. of Civil Engrg., State Univ. of New York at Buffalo, Buffalo, N. Y. 14214.

(d) Experimental and field investigations.

(e) Determine turbulence characteristics in free-surface tilting flume and relate to boundary roughness; measure time average sediment concentration, local and mean boundary shear stress and relate to shear strength and density and structure of cohesive soil material; and establish regime behavior of natural channels as influenced by hydraulic flow, changes in flow patterns, sediment and channel alluvium characteristics.

(g) Turbulence intensity and distribution in relation to bed roughness and shear velocities are being developed by hot-film anemometer. Bed sills and experimental cellular revetment have proved effective in controlling bank and stream erosion in Buffalo Creek (New York) after more than 10 years after construction. Design of the horizontal spacing and height of sills is dependent on water surface profile, erosive forces and resistive character of the channel.

(h) "Experiences with Bed Sills on Stream Stabilization," Proc. ASCE, J. Waterways and Harbors Division, Vol. 95, No. WW3, Aug. 1969.

"Erosion of Cohesive Soil and Channel Stabilization," Emmanuel Partheniades and Robert E. Paaswell, Civil Engrg. Rep. No. 18, State Univ. of New York at Buffalo, Buffalo, N. Y. 14214.

"Erodibility of Channels with Cohesive Boundary," Emmanuel Partheniades and Robert E. Paaswell, J. Hydraulics Div., ASCE, Vol. 96, No. HY3, pp. 755-772, March 1970.

"Measurement of Turbulence in Water," Discussion, by Emmanuel Partheniades and P. H. Blinco, Proc. ASCE, J. Hydraulics Div., Vol. 95, No. HYL, Jan. 1969.

"Some Turbulence Measurements in Open Channels Flow," Discussion, by Emmanuel Partheniades and P. H. Blinco, Proc. ASCE, J. Hydraulics Div., Vol. 96, No. HYL, Jan. 1970.

(4819)

IMPROVED DRAINAGE SYSTEMS FOR AGRICULTURAL LANDS.

(b) Cooperative with the Vermont Agricultural Experiment Station and the Soil Conservation Service.

(c) Mr. Joseph Bornstein, Agricultural Engr., Univ. of Vermont, Burlington, Vt. 05401.

(d) Field investigation both basic and applied research.

(e) The purpose of this study is to develop and evaluate drainage practices for sloping hardpan lands of the Northeast. This involves development of techniques for determining directional components

of subsurface water flow before and after installation of drainage treatments. Surface and subsurface drainage practices are instrumented to measure runoff from rainfall and snowmelt. Measure has been made of the seasonal changes in soil moisture in relation to drainage treatment; evaluation of crop root development above and in fragipan layer, characterization of moisture-tension relationships of disturbed and undisturbed fragipan samples, including through the freeze-thaw cycle.

Instrumentation of this project is completed and six years data are available on diversion ditch runoff and tile outflow. Extensive piezometric and soil moisture change and crop data are also available. Crop results include yield changes in botanical analysis, winterkill and alfalfa crown rot vs. drainage and plant heights. A seepage pit has yielded ground water flow data by horizons.

(h) "Insulated Soil Heating Systems to Prevent Frost Heaving of Field Instrumentation," J. Bornstein, R. R. Alberts and G. R. Benoit. J. Agr. Engr. Res. 14:100-103, 1969.

"Tile Drainage of a Sloping Fragipan Soil," T. J. Thiel and J. Bornstein. Trans. Amer. Soc. Agr. Engrs. 8(4):555-557, 1965.

"Drainage Research in Vermont," J. Bornstein and G. R. Benoit. USDA, ARS brochure, 1966.

"Effects of Sloping Land Drainage on Alfalfa Crown Rot," K. D. Fisher, G. R. Benoit and J. Bornstein. Phytopathology. 59:386-388, 1969.

(4820)

HYDRODYNAMICS OF CHANNEL SYSTEMS IN AGRICULTURAL WATERSHEDS.

(b) Cooperative efforts on occasion.

(c) Mr. H. N. Holtan, Director, USDA Hydrograph Lab., ARS-SWC, Beltsville, Md. 20705.

(d) Basic and applied research.

(e) Specific objectives of this project are to translate the complete system of hydrodynamics, i.e., the equation of continuity, the equation of state, and the equation of motion of fluids to a system appropriate to steady or unsteady flow (with lateral inflow and outflow) on land surfaces and through open channels; to define appropriate watershed and channel initial values and boundary conditions such as, surface or channel roughness, vegetation, materials and geometry, to insure meaningful watershed solutions to the hydrodynamical equations; to develop feasible numerical methods for solving hydrodynamic equations on analog or digital computers; and to work with other members of the USDA Hydrograph Lab. to verify the surface dynamic aspects of a mathematical model of watershed performance.

(g) A computational overland flow system is now being utilized which was derived from more than 200 observed hydrographs on impermeable surfaces. It was found for lengths up to 500 feet, slopes up to 2 percent, and rain rates up to 8 inches per hour that a single dimensionless distribution would accurately describe all of the observed hydrographs developed from long steady rain rates. The dimensionless distribution relates discharge normalized by the input or rainfall rate to the associated time normalized by the lag time (50% of rain volume to 50% of runoff volume). This new lag time was derived from physical considerations, and was shown to be a function of the length, slope and roughness of the plot and the attenuating rain rate. The computational system was developed so that overland flow hydrographs could be synthesized for unsteady, nonuniform rainstorms over nonuniform hillslopes. The

length, slope, roughness and rain rates are used to calculate the lag times and an overland flow hydrograph is predicted at the end of the slope. This system of computations is extremely flexible, yet simple. The mathematical model can be used immediately in hydrologic design for urban areas and the mathematical model will be used in search for surface runoff principles.

- (h) "A Kinematic Model of Surface Runoff Response," D. E. Overton and D. L. Brakensiek, Proc. International Symposium on Results of Research on Representative and Experimental Basins, Dec. 1970, IASH, Wellington, New Zealand.

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U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

NORTHERN PLAINS BRANCH, P. O. Box E, Fort Collins, Colorado 80521. Dr. C. E. Evans, Branch Chief.

(4826)

FLOW IN POROUS MEDIA IN RELATION TO DRAINAGE DESIGN AND DISPOSAL OF POLLUTANTS.

- (c) Mr. Harold R. Duke, Agric. Engr., ARS, Engrg. Research Center, Colorado State Univ. Foothills Campus, Fort Collins, Colo. 80521.
- (d) Theoretical and experimental; applied research.
- (e) A highly instrumented sand tank model of a parallel drain system is being used to determine the potential distribution and contribution of the partially saturated zone to the drain performance. The purpose is to provide an accurate means of drain design in fine-textured soil.
- (g) A comprehensive theory has been developed to describe the physical processes of desaturation in porous media. This theory describes three distinct processes contributing to desaturation, and gives a mathematical description of each process. Two-dimensional similitude criteria have been verified for the partially saturated flow systems.
- (h) "The Desaturation of Porous Materials," N. F. White, Ph.D. Dissertation, Colo. State Univ., Fort Collins, 113 pp., 1968.

(4827)

DESIGN, OPERATION AND EFFICIENCY OF AUTOMATIC IRRIGATION SYSTEMS. (COMBINED WITH 5567.)

(4832)

DRAINAGE FOR RECLAMATION OF SALT-AFFECTED NON-IRRIGATED SOILS IN RED RIVER VALLEY, NORTH DAKOTA.

(5567)

AUTOMATION OF WATER DISTRIBUTION SYSTEMS FOR SURFACE IRRIGATION.

- (c) Dr. H. R. Haise, Soil Scientist, ARS, P. O. Box E, Ft. Collins, Colorado 80521.
- (d) Laboratory and field project; applied research.
- (e) To develop labor-saving devices for surface application of irrigation water to farm fields for more efficient use of existing water supplies. Hydraulics of flow in border strips and furrows as affected by stream site, slope, crop retardance, soil roughness and intake rate is evaluated as it relates to type of automation.
- (g) Automation systems have been developed utilizing both pneumatic and hydraulic components to open and close irrigation gates in the field. Both types of system are operated from a central control point where predetermined water release times can be programmed. Turnout gates in lined, open ditches that can be operated by low-cost plastic hydraulic cylinders have been installed and operated at three field

locations. Associated check structures are controlled automatically in proper sequence with the gates. At another location a field planted to row crops has been automated using hydraulically controlled pipe gates (designed specifically for this use) and an automatic water reuse system. Construction of large (10" by 10" throat) fluidic diverters of thin shell concrete for use in controlling streams of irrigation water has been proven feasible in the laboratory. A numerical solution solving the hydrodynamic equations for calculating the rate of advance and water surface profiles has been successfully programmed for the computer. Simulations of irrigations have been made for borders up to 800 feet in length.

- (h) "Hydraulically Controlled Butterfly Gates in Farm Lateral Turnouts for Automation of Surface Irrigation Systems," Howard R. Haise, E. Gordon Kruse and Leonard Erie, Ag. Engr. 50(4):212-216. April 1969.

"Automation of Surface Irrigation Systems: The State of the Art," H. R. Haise and E. G. Kruse, ASCE, I&D Div., Vol. 95, IR 4, pp. 503-516, Dec. 1969.

"Intake Function and Border Irrigation," James R. Gilley, M. S. Thesis, Dept. of Agric. Engrg., Colo. State Univ., Fort Collins, June 1968.

"Low Gradient Border Irrigation," Martin Payne, M. S. Thesis, Dept. of Agric. Engrg., Colo. State Univ., Fort Collins, March 1969.

(7001)

SIMULATION OF HYDROLOGIC SYSTEMS.

- (b) In cooperation with Colorado State University.
- (c) Dr. David A. Woolhiser, Research Hydraulic Engr., Engrg. Research Center, Colorado State Univ., Foothills Campus, Fort Collins, Colo. 80521.
- (d) Theoretical and experimental. Basic and applied.
- (e) Purpose of the project is to develop procedures for numerically simulating the surface runoff hydrograph of small watersheds and to develop objective techniques for transforming complex watersheds into simple combinations of overland flow planes and channels for numerical simulation.
- (g) In cooperation with Colorado State University personnel, a rainfall simulation system was designed and installed on the Colorado State University Experimental Rainfall-Runoff Facility. Experiments on the converging section of this facility were performed during September and October, 1969. A mathematical model incorporating Richards equation for vertical unsaturated flow in a porous medium has been combined with the kinematic cascade to simulate infiltration and overland flow simultaneously. An experimental facility has been constructed to test the accuracy of this mathematical model.
- (h) "Overland Flow on a Converging Surface," D. A. Woolhiser. Trans. ASAE, Vol. 12, No. 4, pp. 460-462, 1969.
- "A Kinematic Overland Flow Model and Its Optimization," David F. Kibler. Ph.D. Thesis, Colo. State Univ., Fort Collins, 1968.

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U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

NORTHWEST BRANCH, P. O. Box 1187, Boise, Idaho 83701. Mr. J. C. Stephens, Branch Chief.

(3550)

SPRINKLER IRRIGATION SYSTEM DESIGN AND OPERATION IN THE NORTHWEST. (COMBINED WITH 5570.)

(3553)
SURFACE IRRIGATION SYSTEM DESIGN AND AUTOMATION IN
THE NORTHWEST. (COMBINED WITH 5209.)

(5209)
STRUCTURES AND TECHNIQUES FOR IRRIGATION WATER CON-
TROL AND MEASUREMENT.

- (c) A. S. Humpherys, Agric. Engr., Snake River Con-
servation Research Center, Route 1, Box 186,
Kimberly, Idaho.
- (d) Experimental, field investigations; applied re-
search and development.
- (e) To develop devices, techniques, and improved
structures for manual, semiautomatic, and auto-
matic irrigation water control. To develop im-
proved devices and methods for economical and
accurate measurement of irrigation water flow in
open channels and closed conduits. Devices,
methods and structures are developed and tested
in the laboratory and the field. Laboratory and
field data are collected to evaluate the design,
accuracy, performance, adaptability to field
conditions, and to improve current design crite-
ria.
- (g) Center-of-pressure and sinking float automatic
irrigation gates have been developed in the
laboratory and are being field tested. These
may be used individually or as companion struc-
tures to automate new or existing farm irrigation
systems. They are self-operating and do not re-
quire energy from an outside source. They can be
designed for use in either lined or unlined ditches
and are particularly well-suited for border or
flood irrigation.
- Various designs of farm drop-check structures in
the 1-3 cfs range were field tested. The scour
pattern downstream from these structures was
affected by end sills. When sills were used,
bank erosion accounted for a large portion of the
total scour volume. Whereas, without end sills,
bed degradation accounted for most of the total
scour volume. Structures using gravel or small
riprap lined basins had the least scour volume
and also were the most economical.
- Procedures have been developed for installing con-
crete trapezoidal measuring flumes on farm irriga-
tion ditches. These cast-in-place flumes provide
a low cost and dependable means of measuring farm
irrigation water.
- (h) "Cast-in-Place Concrete Trapezoidal Measuring
Flumes." J. A. Bondurant, A. S. Humpherys, and
A. R. Robinson, ARS 41-155, 16 pp., 1969.
- "Automatic Mechanical Irrigation Gates." A. S.
Humpherys, 1968 and 1969. (1) Int. Comm. Irrig.
and Drain., 7th Congr. Proc., Mexico City, R. 17,
Question 24, pp. 24.251-24.261, 1969. (2) Agr.
Res. 17(4):7, 1968.
- "Automated Surface Irrigation Equipment." A. S.
Humpherys, 1968 and 1969. (1) Irrigation Opera-
tor's Workshop Proc., Utah State Univ., Logan
(January 6-8, 1969), pp. 121-133. (2) Idaho
Farmer 87(6):11, 15, and 16, March 20, 1969.
- (3) Utah Farmer 89(6):20, 22, and 23, March 20,
1969. (4) Oregon Farmer 92(6):20-23, March 20,
1969. (5) Washington Farmer 94(6):23-26, March
20, 1969. (7) Montana Farmer-Stockman 56(13):34-
37, March 20, 1969.
- "Mechanical Structures for Farm Irrigation." A.
S. Humpherys, 1968 and 1969. (1) Am. Soc. Civil
Engr., Irrig. and Drain. Div. Spec. Conf. Proc.,
Phoenix, Ariz., Nov. 1968, pp. 253-279. (2) Am.
Soc. Civil Engr. 95(IR4):463-479, 1969.

(5570)
IMPROVING FARM AND DISTRICT IRRIGATION EFFICIENCY IN
THE NORTHWEST.

- (b) Cooperative with the U. S. Bureau of Reclamation
and Idaho Agricultural Experiment Station.
- (c) M. E. Jensen, Director (Agric. Engr.), Snake
River Conservation Research Center, Route 1,
Box 186, Kimberly, Idaho.
- (d) Field investigations; applied research.
- (e) Develop and test improved irrigation practices in
the field for various crops, soils, and fertilizer
levels to determine their effects on water use
efficiency, crop yield and quality. Measure
microclimatic factors under field conditions and
determine the relationship between water use,
crop growth, and microclimatic conditions. Devel-
op procedures that can be used by management ser-
vice companies to schedule irrigations using
climate, and soil and crop characteristics.
- Develop and test improved surface and sprinkler
irrigation practices in the field and determine
their effects on water use efficiency, and crop
yield and quality.
- (g) Irrigation scheduling using climate-crop-soil
data has been shown to be practical and economical
now even though further refinement is needed. The
potential economic returns can exceed the costs
of such a service by several-fold, depending on
the starting point. The modern farmer desires a
service such as this to increase his net returns
in irrigation agriculture. Farmers who depend
only on rainfall can effectively use this informa-
tion to make fertilizer decisions if soil moisture
conditions are adequate to sustain higher yields.
- Border irrigation techniques can be used with
furrows on slopes up to 0.4%. The amount applied
with this method of irrigation is a function of
both the hydraulics involved and the application
rate. The depth of water applied by primary flow
averaged from 1.09 inches on a 0.4% slope to 1.87
inches for nine irrigations on a 0.1% slope on
660-foot runs.
- Evapotranspiration was calculated for a sugar beet
crop from energy balance measurements using a
mobile instrument laboratory, and measured for a
crop of alfalfa with a sensitive weighing lysim-
eter. ET was related to the stage of growth and
degree of crop cover, the surface soil water sta-
tus, the microclimatic conditions, and the poten-
tial for evaporative water loss. The accumulated
results of this and previous years indicate a
need for an improved reference potential for es-
timating or predicting evapotranspiration for
arid, irrigated regions because of the magnitude
of the advected sensible heat from surrounding
areas that contributes to ET.
- A multirun irrigation system was installed on an
experimental field of pinto beans. The effect of
pattern overlap due to method of sequencing
different distribution lines is currently being
investigated.
- (h) "Automated Pumping Stations for Reuse of Irriga-
tion Runoff Water." J. A. Bondurant, 1969. Comm.
Int. du Genie Rural, VII Congr., Oct. 6-13, 1969,
Documentation 1, Sec. 1, 1-4, pp. 139-143.
- "Design of Recirculating Irrigation Systems." J.
A. Bondurant, 1969. (1) Trans. Am. Soc. Agr.
Engr. 12(2):195-198, 201. (2) Condensed in Agr.
Res. 18(9):11.
- "General Report (E) Question 23, Water Require-
ments of Crops." M. E. Jensen, 1969. Int. Comm.
on Irrig. and Drain., 7th Congr. on Irrig. and
Drain., Mexico City, April, pp. G23.3-G23.44.
- "Scheduling Irrigations Using Computers." M. E.
Jensen, 1969. J. Soil and Water Conserv. 24(5):
193-195.

"Plant and Irrigation Water Requirements." M. E. Jensen, 1969. Revision of Chapter V, Sprinkler Irrigation, Third Ed., Sprinkler Irrigation Assoc., Washington, D. C. pp. 94-118.

"Nonsteady-State Drainage of Fluid from Porous Media." M. E. Jensen, 1967. Proc. ASCE 93(1R3): 209-231.

"Scheduling Irrigations Using Climate-Crop-Soil Data." M. E. Jensen, D. C. N. Robb, and C. E. Franzoy, 1970. Proc. ASCE 96(1R1):25-38.

"Sugar Beet Yields Unaffected by Afternoon Wilt-ing." R. A. Kohl and J. W. Cary, 1969. J. Am. Soc. of Sugar Beet Tech. 15(5):416-421.

"Better Sprinkling on Small Research Plots." R. A. Kohl, C. H. Pair, and T. W. Massee, 1969. Agr. Engr. 50(2):87.

"Evaluation of Mechanized Sprinkler Equipment." C. H. Pair, 1969. Proc. 57th Ann. Oregon Reclam. Assoc. Conf., Ontario, Ore., Oct. 28-29, 1968. pp. 37-44.

"Water Distribution Under Sprinkler Systems Used in the United States." C. H. Pair, 1969. Comm. Int. du Genie Rural, 7th Congr., Oct. 6-13, 1969. Documentation 1, Sec. 1, 1-4, pp. 219-228.

"Tests Show Sprinkler Values." C. H. Pair, 1969. Reclam. Era, pp. 24-27.

"Operation and Maintenance." Chapter XI, Sprinkler Irrigation, Third Ed., Sprinkler Irrigation Assoc., Wash., D. C., pp. 311-324.

"Sprinkler Irrigation." Third Ed., C. H. Pair (Editor-in-Chief), Walter H. Hinz, Crawford Reid, and Kenneth R. Frost (Editorial Committee). Sprinkler Irrigation Assoc., Wash., D. C., 444 pp.

"Sprinkler Irrigation Spray Temperatures." C. H. Pair, J. L. Wright, and M. E. Jensen, 1969. Trans. Am. Soc. Agr. Engr. 12(3):314-315.

Abstract: "Evaporation from Some Irrigated Crops as Related to Stage of Growth and Soil-Water Status." J. L. Wright, 1969. Agron. Abs. 1968 Annual Meetings, Nov. 10-15, 1968, p. 129. (Manuscript in rough draft stage for publication in Agron. J.)

(5981)

DRAINAGE SYSTEMS FOR IRRIGATED AREAS IN THE NORTHWEST.

(c) M. E. Jensen, Director (Agric. Engr.), Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho.

(d) Experimental, field investigations; applied research.

(e) Natural drainage rates in selected areas are determined using water balance techniques which account for evapotranspiration, storage of water in the soil, and flow in surface and subsurface drains. Mathematical models of the projects are then developed to evaluate the effects of changing one or more components of the system. Numerical solutions of unsaturated flow in soil moisture depletion problems are used to predict minimum drainage requirements under improved irrigation practices and various soil-water quality combinations.

(g) A water budget study of the Minidoka Irrigation District indicated that natural drainage under the high water table area is primarily slow vertical drainage with little influence from nearby areas of high water applications. Canal seepage and heavy spring irrigations combine to exceed the slow drainage rate of the deep restricting layers and cause the annual rise of the water table. Canal seepage makes a significant contribution to water table problems under a large part of the Minidoka Irrigation District. Control of the seepage would cost from \$25 to \$45 per acre of the total area served by the various parts of the

system.

Estimates of drainage from a soil profile are needed in scheduling irrigations. These estimates can be made using an experimentally derived relationship between the total volume of water in the profile and drainage rate, and provided sufficient water has been applied so estimates of drainage made using a single time increment for the day and the water content after the previous day will be too large unless evapotranspiration for the day is subtracted first, or several time increments per day are used in the calculations.

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U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division

SOUTHERN BRANCH, P. O. Box 1072, Athens, Georgia 30601.
Dr. G. R. Burns, Branch Chief.

(3871)

SEDIMENT TRANSPORT IN STREAM CHANNELS.

(b) Cooperative with Univ. of Mississippi and Mississippi State University.

(c) Messrs. Joe C. Willis and A. J. Bowie, Hydraulic Engrs., and Dr. Neil L. Coleman, Geologist, USDA Sedimentation Lab., P. O. Box 30, Oxford, Miss. 38655.

(d) Experimental; basic and applied research.

(e) Investigate all aspects of sediment transport including: "wash load," bed load, suspended load, bed material transport, and total sediment transport in alluvial channels. Determine by laboratory and field experiments the effects of flow characteristics, physical properties of bed forms and bed material on sediment transport in alluvial channels. Design, develop and test instruments and techniques for measurement of water runoff and sediment discharge.

(g) Sediment transport data from a 100-foot flume and from other flume investigations were found to describe a unified correlation. The density-corrected, average sediment concentration was found to correlate well with the Froude number and a grain diameter similitude number. The resulting graphical relationship should serve as a reliable means for estimating the capacity of open channel flows to transport sands.

In a study of sediment suspension, logarithms of the concentration values from various elevations in the flow were found to plot as a straight line with relative depth on log-probability paper. The integral over the flow depth of the mathematical model describing these lines was found to give a consistent estimate of the average sediment concentration as determined from total load measurements.

The sediment transfer coefficient in an open channel flow does not follow the classical model which predicts a zero value at the bed and at the water surface, and a maximum value near mid-depth. Instead, it increases with distance from the bed, reaching a maximum value at a height similar in magnitude to the displacement thickness defined in boundary layer theory. The transfer coefficient evidently has a near-constant value in the upper 80 percent of the flow. These characteristics of the sediment transfer coefficient are not dependent on the total amount of material in suspension.

(h) "Field Test of an X-Ray Sediment Concentration Gage." C. E. Murphree, G. C. Bolton, J. R. McHenry and D. A. Parsons, Proc. ASCE J. Hydr. Div., Vol. 94, No. HY2, Mar. 1968.

"Runoff and Erosion Characteristics of the Brown Loam Soils," C. E. Carter, C. W. Doty, and B. R. Carroll, ASAE, Agricultural Engrg., Vol. 49, No. 5, p. 296, May 1968.

Closure: 'Field Test of an X-Ray Sediment Concentration Gage,' C. E. Murphee, G. C. Bolton, J. R. McHenry, and D. A. Parsons, ASCE J. Hydr. Div., Vol. 96, No. HY1, pp. 255-256, Jan. 1970.

"A New Examination of Sediment Suspension in Open Channels," N. L. Coleman, IAHR, J. of Hydr. Res., Vol. 7, No. 1, pp. 67-82, 1969.

A Discussion: 'Free Surface Shear Flow Over a Wavy Bed,' N. L. Coleman, ASCE J. Hydr. Div., Vol. 95, No. HY1, pp. 524-526, 1969.

A Discussion: 'Similitude Theory Applied to Correlation of Flume Sediment Transport Data,' J. C. Willis and N. L. Coleman, AGU, Water Resources Res., Vol. 5, No. 4, pp. 921-923, 1969.

A Discussion: 'Definitive Computations of Sand Discharge in Rivers,' J. C. Willis, ASCE J. Hydr. Div., Vol. 95, No. HY6, pp. 2185-2189, Nov. 1969.

"Predicting Sediment Yields from Complex Watersheds," J. A. Spraberry and A. J. Bowie, ASAE Trans., Vol. 12, No. 2, pp. 199-201, 1969.

"Sampling and Analysis of Coarse Riverbed Sediments," T. C. Muir. Proc., Mississippi Water Resources Inst. Conf., pp. 73-83, April 1969.

(4316)
DESIGN CRITERIA FOR WATER CONTROL STRUCTURES AND CHANNEL STABILIZATION.

(b) Cooperative with Univ. of Mississippi and Mississippi State University.

(c) Mr. D. A. Parsons, Hydraulic Engr., and Dr. Neil L. Coleman, Geologist, USDA Sedimentation Lab., P. O. Box 30, Oxford, Miss. 38655.

(d) Field and laboratory investigations; basic and applied research.

(e) Develop and evaluate techniques and criteria for the design, stabilization, and maintenance of stream channels. Investigate by model and field studies methods and means of channel stabilization and protection. Areas of investigation include: the influence of plan geometry and channel shapes; the spectrum of flood flow values; flow velocities, depths, and slopes; flow reduction schemes; and the use of engineering works, vegetation, etc., to reduce channel boundary velocities and protect the channel lining.

(g) Changes in cross-sectional area in selected channels in the upper Pigeon Roost Creek Watershed in north Mississippi indicate sediment production from this source of about 0.8 tons per acre of drainage area per year. This is about 20 percent of the average annual sediment discharge in these streams and does not include probable significant contributions from many smaller headwater channels. A major flood in Tillatoba Creek in north Mississippi severely tested the streambank protection work that had been applied. Parallel rows of piling with spaced boards along the stream side, strings of cabled concrete jacks, and rows of cabled automobile bodies had been placed along severely eroding banks in bends. Only small damage was done to the revetment by a major flood, demonstrating the strength of the installations. A change in the Froude number of the flow from 0.9 to 0.5 had little effect upon the positions of the areas of maximum boundary shear stress in a laboratory channel with a 90° turn. The channel cross-sectional was trapezoidal, the surface width about 10 times the depth, and the radius of the bend one and one-half to two times the surface width, depending upon the flow.

(h) A Discussion: 'River-Bed Degradation Below Dams,' J. C. Willis, ASCE J. Hydr. Div., Vol. 94, No. HY5,

pp. 1346-1350, Sept. 1968.

(4317)

STREAM CHANNEL MORPHOLOGY AND STABILITY.

(b) Cooperative with Univ. of Mississippi and Mississippi State University.

(c) Dr. Earl H. Grissinger, Soil Scientist, Mr. Donald A. Parsons, Hydraulic Engr. and Director, and Dr. Neil L. Coleman, Geologist.

(d) Experimental; applied and basic research.

(e) Investigations of prevailing horizontal and vertical forms of stream channels and the processes and forces that create them, including bed forms and resistance to flow in alluvial channels, to acquire knowledge that will provide engineering solutions to problems of channel stability. Determine by both laboratory and field experiments the effects of various hydraulic and mineralogical parameters on channel geometry and stability; also the influences of horizontal channel geometry on the flow parameters. The latter are interdependent. Hydraulic parameters include: velocity head, boundary shear stress, Froude and Reynolds numbers, and hydraulic gradient. The inherent and the environmental factors affecting cohesiveness of channel periphery materials will be investigated.

(g) In studies of the principles of stable channels, a first-approximation model has been developed to describe the laboratory-determined erodibility of cohesive materials based on the following relationships: (1) Erodibility varies with the rate of water entry into the sample; (2) erodibility varies with the square of the distance between cohesive particles; and (3) erodibility varies with the type of clay.

The field data collection phase of a massive study of 124 small waterways in southeastern Nebraska has been completed. The stability of these channels, or lack of it, is to be related to the climatic, watershed, and soils conditions.

(4331)

PRINCIPLES OF AND PRACTICES FOR CONTROL OF SOIL EROSION BY WATER.

(4332)

DRAINAGE REQUIREMENTS OF CROPS AND SYSTEMS DESIGNS IN LOWER MISSISSIPPI DELTA (THE EFFECTS OF ROW LENGTH AND SLOPE ON THE REMOVAL AND APPLICATION OF SURFACE WATER).

(c) Cade E. Carter, Agricultural Engr., P. O. Drawer U, University Station, Baton Rouge, La. 70803.

(d) Experimental, basic and applied.

(e) Design criteria for drainage ditches in the lower Mississippi Delta are being determined from field-size runoff plots. This experiment, on Moon clay loam soil, consists of eight 10-acre blocks of land with two blocks each graded 0.10, 0.15, 0.20, and 0.25 percent. Within each block are rows 500, 700, 900, and 1100 feet in length. Each of the 32 plots is equipped with runoff measuring and recording devices. Runoff rates and amounts are related to the row grade and row length treatments to determine useful design information.

(g) Data show that peak rate and amount of surface water removal can be predicted from the parameters of maximum rainfall intensity for 35 minutes, row grade and length, and the available soil moisture storage capacity. Prediction equations have been developed.

(4841)

SURFACE AND SUBSURFACE FARM WATER SUPPLIES IN THE SOUTHERN COASTAL PLAINS. (COMBINED WITH 4332.)

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHERN PLAINS BRANCH, ARS-USDA, Bushland, Texas 79012.
Dr. J. R. Johnson, Branch Chief.

(4337)

HYDROMECHANICS OF OVERLAND, CHANNEL AND FLOODPLAIN FLOWS.

- (b) Cooperative with the Oklahoma Agricultural Expt. Sta.
- (c) Dr. D. K. McCool, Agricultural Engr., P. O. Box 551, Stillwater, Okla. 74074.
- (d) Experimental; applied research.
- (e) Obtain data needed for the design of channels used in soil and water conservation works, for testing theories of the hydromechanics of surface flow, and for developing hydraulic explanations of hydrologic phenomena. Experimental channels are built on the laboratory grounds, planted to grasses or lined with artificial materials and then subjected to controlled flows of water. Test flows can be steady or unsteady, uniform or non-uniform, or in one channel, can be spatially varied as well. Flow retardance coefficients, permissible velocities, energy and momentum coefficients, and flow profiles are determined.
- (g) Manning's n values for vegetation lined channels are a function of depth and velocity of flow as well as the physical characteristics of the vegetation. Permissible velocities are influenced by the physical characteristics of the vegetal cover, the textures of the soil, and by the steepness of the channel. Permissible velocity and n-value data are given in a handbook of channel design prepared by the laboratory. Spatially varied flow equations now in use can predict flow profiles accurately only if realistic momentum coefficients are used.

(4341)

STREAM CHANNEL MORPHOLOGY IN THE SOUTHERN PLAINS.

(4844)

DRAINAGE REQUIREMENTS OF CROPS AND SYSTEMS DESIGN -- RIO GRANDE PLAIN.

(4848)

WATER EROSION CONTROL PRACTICES FOR THE TEXAS BLACKLAND PRAIRIE.

(5216)

PRINCIPLES, FACILITIES AND SYSTEMS FOR GROUND WATER RECHARGE -- SOUTHERN PLAINS.

(7002)

DEVELOPMENT AND HYDRAULIC TESTING OF CONSERVATION STRUCTURES AND WATERFLOW MEASURING DEVICES (COMBINED ITEMS 4335 AND 4336 FROM THE 1968 REPORT).

See U. S. Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division, Cornbelt Branch, Project 1723 and Illinois State Water Survey Division, Project 1865.

- (b) Cooperative with the Oklahoma Agric. Exp. Sta.
- (c) Mr. W. O. Ree, Engineer in Charge, P. O. Box 551, Stillwater, Okla. 74074.
- (d) Experimental, applied research.
- (e) Develop and test hydraulic structures for soil and water conservation works. Test small scale and full size models of structures and appurtenances in laboratory basins. Determine general hydraulic performance, head loss coefficients, pressure coefficients and related hydraulic phenomena. Structures required for flow measurement in the hydrology research program of the Agri-

cultural Research Service, U. S. Department of Agriculture, are developed for sites where standard structures are not practical. Such sites include steep sand-laden streams and streams having very flat gradients. Consideration is given to scour, backwater and channel control effects. Modifications to existing drainage structures to make them suitable for runoff measurement are devised and tested.

- (g) Trash racks on closed conduit spillways for floodwater retarding reservoirs have been tested with clear water flows and with flows carrying hay or sticks. Relative efficiencies of various rack designs have been determined. A complex of channels and structures comprising an urban floodwater disposal system has been tested. Nine large supercritical flow measuring flumes with capacities up to 22,500 cfs have been designed and calibrated. Eight highway culverts equipped with V-notch weirs have been calibrated. Model studies of two highway bridge sites have been made to determine the effect of the addition of weirs for low flow measurement. Protection of the bridge foundations from scour was a consideration.
- (h) "Crest Losses for Two-Way Drop Inlet," G. G. Hebaus, ASCE Hydraul. Div. Jour. 6570 (HY3):919-940. May 1969.
- "Hydraulic Model Studies for Urban Channel Improvement Works," G. G. Hebaus and W. R. Winn, Trans. ASAE, Vol. 12, No. 6, Nov.-Dec. 1969.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHWEST BRANCH, P. O. Box 2326, Riverside, California 92506. Mr. W. W. Donnan, Branch Chief.

(2181)

RECHARGING GROUND WATER FOR AGRICULTURAL AND URBAN USES.

(3558)

COLLOIDAL MATERIALS FOR CONTROL OF SEEPAGE FROM CANALS AND PONDS IN NEVADA. (WORK TERMINATED.)

(4358)

FLOOD WAVE MOVEMENT IN NATURAL EPHEMERAL STREAM CHANNELS.

- (b) Cooperative with the Arizona and New Mexico Agricultural Expt. Stations, and the USDA Soil Conservation Service.
- (c) Mr. K. G. Renard, Hydraulic Engr., 442 East Seventh St., Tucson, Ariz. 85705.
- (d) Experimental, field investigation.
- (e) Water-level recorders are located at 2,000-foot intervals in a 2.6-mile reach of natural channel. The reach has a precalibrated flume at the inlet and at the outlet, and the major tributary inflow is measured. Flood waves produced by convective thunderstorms in ephemeral streams are being studied.
- (g) The velocity of wave fronts on dry channels appears to be relatively independent of discharge. Peak discharge velocities are higher than the wave front and can be approximated by using Manning roughness values of 1/2 that for the flow front. Impulse waves generated by high intensity thunderstorms move off the land into channels where they override existing flows until the catch-up with the flow front. The downstream hydrograph thus has a shape distortion with the rising limb being a shorter period than that at the upper station.
- (h) "Hydrographs of Ephemeral Streams in the Southwest," K. G. Renard and R. V. Keppel, J. Hydraul.

lics Div., ASCE, Vol. 92, No. HY2, pp. 35-53, March 1966. (a) Closure to this article, K. G. Renard, J. Hydraulics Div., ASCE, Vol. 93, No. HY4, pp. 275-277, 1967. (b) Digest of this article, K. G. Renard and R. V. Keppel, Trans. ASCE, Vol. 132, pp. 388-389, 1967. "Analysis of Two Runoff-Producing Southwest Thunderstorms," H. B. Osborn and K. G. Renard, J. of Hydrology, 8(3), pp. 282-302, 1969. "The Hydrology of Semiarid Rangeland Watersheds," K. G. Renard, ARS-41-162, 1970.

(4854) DRAINAGE SYSTEMS FOR THE IMPERIAL VALLEY.

(5219) EFFICIENT IRRIGATION AND AGRICULTURAL WATER USE.

(c) Mr. Lloyd E. Myers, Research Hydraulic Engr., USDA-ARS, U. S. Water Conservation Lab., 4331 East Broadway, Phoenix, Arizona 85040.
(d) Experimental and theoretical.

(e) The purpose of this research is to determine the process involved in evapotranspiration and the effect of climate for various crops; and to develop methods of water application to utilize energy and conserve moisture.

(g) Designed critical depth flumes by computer techniques. Developed method for measuring infrared emittances of soils, leaves, and other surfaces. Completed study of elbow meter to measure pipe flow.

(h) "Closure: Evaluation of Pipe Elbows as Flow Meters," John A. Replogle, Lloyd E. Myers and K. J. Brust, J. Irrig. and Drain. Div., Proc. ASCE, 94 (IR3):335-339. Sept. 1968.

"Digest: Evaluation of Pipe Elbows as Flow Meters," John A. Replogle, Lloyd E. Myers, and K. J. Brust, Amer. Soc. Civil Engin. Trans. 133:373-374. 1968.

"Ambient Temperature Effects in Infrared Thermometry," Ray D. Jackson and Sherwood B. Idso, Agron. J. 61(2):324-325. Mar.-Apr. 1969.

"Flow Measurement with Critical Depth Flumes," John A. Replogle, Internat'l. Comm. on Irrig. and Drain., 7th Congress Proc., Mexico City, April 1969. Question 24, R. 15, pp. 24.215-24.235.

"Automating Surface Irrigation," Howard R. Haise, G. E. Kruse and Leonard J. Erie, Agric. Engin. 50(4):212-216. April 1969.

"Comparison of Two Methods for Determining Infrared Emittance of Bare Soils," Sherwood B. Idso and Ray D. Jackson, J. Appl. Meteorol. 8(1):168-169. Feb. 1969.

(5220) REDUCING SALT DAMAGE TO SOILS, WATERS, AND PLANTS.

(c) S. L. Rawlins, U. S. Salinity Lab., Box 672, Riverside, California 92502.

(d) Experimental and theoretical; basic research.

(e) Principles involving transport and energy status of water and ions in the soil-plant-atmosphere continuum are under study. Experiments are conducted in greenhouses and growth chambers to test and improve mathematical models.

(g) Instruments for measuring the various components of water potential in the soil and in plants have been perfected. Use of these in conjunction with newly developed environmental control facilities is uncovering the factors influencing water transport from the soil to the atmosphere through plants.

(h) "Measuring Soil Salinity," J. D. Oster, Calif. Citograph 53:280, 282-283, May 1968.

"Design Features of Intact Leaf Thermocouple Psychrometers for Measuring Water Potential," G. J. Hoffman and W. M. Herkelrath, Trans. ASAE

11:631-634, 1968.

"Independent Measurement of Matric and Osmotic Potential of Soil Water," J. D. Oster, S. L. Rawlins, and R. D. Ingalvalson, Soil Sci. Soc. Amer. Proc. 33:188-192, 1969.

"Microchamber for Studying Plant Response to Environmental Factors," G. J. Hoffman, C. J. Phene, and S. L. Rawlins, Trans. ASAE 12:598-601, 1969.

"Simultaneous Cycling of Peltier Thermocouple Psychrometers for Rapid Water Potential Measurements," G. J. Hoffman, W. N. Herkelrath, and R. S. Austin, Agron. J. 61:597-601, 1969.

"Stability of Temperature Measurements Made With P-N Junction Diodes," C. J. Phene, R. S. Austin, G. J. Hoffman, and S. L. Rawlins, Agric. Engrg. 50:684-685, 1969.

"Relation of Water Application to Evaporation and Storage of Soil Water," H. R. Gardner and W. R. Gardner, Soil Sci. Soc. Amer. Proc. 33:192-196, 1969.

(5584) MORPHOLOGY AND STABILITY OF STREAM CHANNELS IN SOUTHERN CALIFORNIA. (WORK TERMINATED.)

(6836) MORPHOLOGY AND STABILITY OF STREAM CHANNELS IN SOUTHWESTERN SEMIARID RANGELANDS. (WORK TERMINATED.)

(6837) INCREASING AND CONSERVING FARM WATER SUPPLIES.

(c) Mr. Lloyd E. Myers; see (5219) above.

(d) Experimental and theoretical.

(e) The purpose of this research is to develop principles, methods, and design criteria for control of seepage, reduction of evaporation, collection and storage of precipitation, and reduction of water losses.

(g) Developed water harvesting techniques for collecting and storing rainfall runoff. Studying effect of water quality on permeability. Developed floating covers to reduce evaporation from water. Improved gamma method for measuring soil water content.

(h) "Hydraulic Conductivity Related to Porosity and Swelling of Soil," J. V. Lagerwerff, F. S. Nakayama, and M. H. Frere, Soil Sci. Soc. Amer. Proc. 33(1):3-11. Jan.-Feb. 1969.

"Creating Hydrophobic Soil for Water Harvesting," Lloyd E. Myers and Gary W. Frasier, Irrig. and Drain. Div., Amer. Soc. Civil Engin. Proc. 95(IR1):43-54. March 1969.

"Current Seepage Reduction Research," Lloyd E. Myers and R. J. Reginato, Second Seepage Symp. Proc., Phoenix, Ariz., 25-27 March 1968. USDA-ARS 41-147, pp. 75-78, April 1969.

"Review of Methods for Measuring and Predicting Seepage," Herman Bower and R. C. Rice, Second Seepage Symp. Proc., Phoenix, Ariz., 25-27 March 1968. USDA-ARS 41-147, pp. 115-120. April 1969.

"Saving Water with Asphalt," Lloyd E. Myers, Amer. Chem. Soc. Symp. on New Uses for Asphalt Proc., Atlantic City, N. J., Sept. 1968, pp. C170-3.

"Synthetic Hydrophobic Soils for Harvesting Precipitation," Dwayne H. Fink and Lloyd E. Myers, Soil Wettability Symp. Proc., Riverside, Calif., May 1968, pp. 221-240, March 1969.

"Second Seepage Symposium Proc., Phoenix, Ariz., 25-27 March 1968," Lloyd E. Myers, Gen. Chairman and Editor, USDA-ARS 141-147, April 1969, 150 pp.

"Water Harvesting and Storage," Keith R. Cooley and L. E. Myers, Seminar on Modifying the Soil and Water Environment for Approaching the Agricultural Potential of the Great Plains Proc., Manhattan, Kansas, 17-19 March 1969. pp. 23-33.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
INSTITUTE OF NORTHERN FORESTRY, P. O. Box 909, Juneau,
Alaska 99801. Richard M. Hurd, Director.

(6970)

EFFECTS OF SHADE COVER ON STREAM TEMPERATURE IN SOUTH-EAST ALASKA.

- (d) Field investigation; applied research.
- (e) The objective of this project is to develop methods for determining the effects of streamside shade cover manipulation on the temperature of streams important in terms of fish, with emphasis on cutting patterns in timber sale layout. Study methods under development include measuring water temperature differences in short (20-yard) stream reaches and temperatures in "slugs" of water as they travel downstream, net solar radiation, and degree and type of shade.
- (g) In exploratory work, stream temperature increases in unshaded 20-yard reaches on clear days averaged 0.071°C and 0.164°C for two different areas. For the same two areas, temperature decreases under shaded conditions averaged 0.060°C and 0.081°C . Under overcast sky conditions the effect of shading was small and for two areas the increases in stream temperature averaged 0.011°C and 0.009°C in 20-yard reaches.
- (h) "Some Effects of Shade Cover on Stream Temperature in Southeast Alaska," William R. Meehan, U. S. Forest Serv. Res. Note PNW-113, 9 pp., illus., January 1970.

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION,
Ogden, Utah 84401. Joseph F. Pechanec, Director.

(6068)

SNOWPACK OUTFLOW.

- (d) Field investigation, basic and applied research.
- (e) The particular phase of the research reported here is an analysis of spring peak flows from selected watersheds in the upper Columbia River basin. Peak flows from Benton Creek (1.5 mi.² area), Boulder Creek (53 mi.² area), and upper South Fork of the Clearwater River (261 mi.² area) were related to meteorological events. Research reported in detail in the 1968 volume of Hydraulic Research deals with development of a snowmelt lysimeter. This research has continued and the publications from it are listed in (h).
- (g) The Benton Creek analysis revealed: (1) Slightly more than one-half of the spring peaks (56 percent) were associated with rain-on-snow events -- less than one-half (44 percent) were associated with snowmelt events; (2) the timing of maximum spring discharge for those years of rain-on-snow peaks was more closely synchronized with the ending day of maximum rainfall than it was for those years of snowmelt peaks with the ending day of maximum temperatures; (3) in some years, heavy rainfall accompanied by relatively high air temperatures affected the generation of spring peak runoff, whereas in other years, heavy rainfall had a strong suppressing effect on air temperature -- so that snowmelt contribution to runoff was probably less and spring peak volumes did not occur; and (4) the highest peak runoff of record was a snowmelt event.
- In somewhat less detail, analysis of the Boulder-South Fork, Clearwater River events revealed that: (1) Three-fourths of all the spring peaks studied in Boulder Creek were associated with snowmelt alone -- in the South Fork, 52 percent of the

spring floods were associated with rain-on-snow events; and (2) the highest generated peaks in Boulder Creek were associated with clear-weather melt -- for a similar period in the South Fork, rainfall events had higher peak generative capacity.

- (h) "The Generation of Spring Peak Flows by Short-Term Meteorological Events," Harold F. Haupt, Bul. Intl. Assoc. Sci. Hydrol. 13(4):65-76, 1968. "A Simple Snowmelt Lysimeter," H. F. Haupt, Water Resources Res. 5(3):714-718, 1969. "A Two-Year Evaluation of the Snowmelt Lysimeter," Harold F. Haupt, Proc. 37th Western Snow Conf. 1969.

(6968)

SOIL EROSION AND CONTROL.

- (d) Field investigation, basic and applied research.
- (e) The purpose of this project is to develop watershed protection requirements for important soil-vegetation complexes in the Intermountain and Northern Rocky Mountain Regions. Special emphasis is being placed on maintaining or improving stability of the extremely erodible soils of the Idaho granitic batholith.
- (g) Research to develop criteria for protection of high-elevation western ranges against high-intensity rainfall confirms the previous conclusion that the most important site factor affecting storm runoff and soil erosion is the density of plant and litter cover. Organic-matter content of the surface soil exerts less important, but still highly significant, influence on the erodibility of range soils representing six different soil texture classes. A highly significant inverse relation exists between organic-matter content and erodibility of silty clay, clay loam, silty clay loam, and silt loam soils. A similar inverse relation occurs in loam soils containing more than an average amount of clay; but in loam soils containing higher than average amounts of sand, this relation becomes significantly positive; erodibility increasing with increases in organic-matter content. Sandy loam soils high in organic matter are significantly more erodible than those low in organic matter. While organic matter binds clay and silt particles into aggregates that resist erosion, it has an adverse effect on aggregation of sand particles. This effect is believed to be associated with hydrophobic characteristics of organic coatings on sand particles, which cause the particles to resist wetting, and, possibly, to possess mutual electrostatic repulsion.
- On soils derived from granite and andesite along the east side of the Sierra Nevada, effectiveness of several major cover types for flood and erosion control depends primarily upon the amount of litter upon the ground. Other site factors that significantly affect storm runoff are the bulk density, macroporosity, texture, and organic matter content of the surface soil. Soil texture, macroporosity, and slope steepness exert additional significant influences on soil erosion. Sites characterized by the three chaparral types -- manzanita (*Arctostaphylos patula*), tobacco brush (*Ceanothus velutinus*), and squaw carpet (*Ceanothus prostratus*) -- have the highest infiltration rates, produce the least runoff, and provide the best flood control. Nonwettable soils restrict infiltration on Jeffrey pine (*Pinus jeffreyi*) sites, permitting high runoff rates that make these sites potential flood sources. Despite high runoff rates, large quantities of litter on undisturbed pine sites guarantee the best protection against soil erosion. Jeffrey

pine sites from which the litter cover has been removed -- either by fire or management activities -- have the lowest infiltration rates, produce the most runoff and soil erosion, and provide the poorest control of floods and sediment. Extreme topographic relief and shallow soils with a high percentage of sand are common in the 16,000-square mile Idaho granitic batholith. Natural erosion results in sediment which is particularly damaging to the valuable anadromous and native fish resource because most of it is transported as bedload. Studies suggest that jammer logging and downhill, high-lead, mobile spar logging increase sheet erosion rates about three times on the logged areas, excluding the effect of roads. When the effect of road construction associated with the jammer logging was included in the evaluation, erosion was increased at least 100 times.

(h) "Effects of Seedbed Treatment on Grass Establishment on Logging Roadbeds in Central Idaho," W. J. Kidd and H. F. Haupt, USDA Forest Serv. Res. Paper INT-53, 1968.

"Forest Service Research in Erosion Control," Otis L. Copeland, Trans. Amer. Soc. Agr. Eng. 12(1):75-79, 1969.

"Infiltrometer Studies of Water-Repellent Soils on the East Slope of the Sierra Nevada," S. B. Hussain, C. M. Skau, S. M. Bashir, and R. O. Meeuwig, Proc. Symp. on Water Repellent Soils, Univ. of Calif., Riverside, 1969.

"Infiltration and Soil Erosion on Coolwater Ridge, Idaho," Richard O. Meeuwig, USDA Forest Serv. Res. Note INT-103, 1969.

"Infiltration and Soil Erosion as Influenced by Vegetation and Soil in Northern Utah," R. O. Meeuwig, J. Range Mgmt. 23:184-187, 1970.

(6969)

SNOWPACK HYDROLOGY.

- (d) Field investigation, basic and applied research.
- (e) The snowpack is being studied in the Wasatch Mountains of Utah and in the northern Rocky Mountains of Idaho for the applied objective of water yield improvement. The particular research reported here pertains to snow interception, evaporation, and snow distribution as affected by contour trenches.
- (g) Storage of intercepted snow in the crowns of two conifer species was studied using a specially designed weighing device. Accumulated storage plotted against accumulated snowfall, using each storm and tree, resulted in sigmoid growth curves. The formula for each curve was derived and a computed curve was fitted to the data. The general equation for snow catch is:

$$I_s = \frac{S}{1 + e^{-k(P - P_0)}}$$

where I_s is interception storage, S is the interception storage capacity of the vegetation, e is the base of the natural logarithm, P is the storm precipitation in inches, k is the constant expressing rate of interception storage, P_0 is the amount of snowfall accumulated at the time of most rapid storage (i.e., the point of inflection of the sigmoid curve). The equation held when trees were bare of snow at the start of the storm, and when trees loaded with dry snow were subjected to a more moist snowfall at higher temperatures than the previous snowfall. Evaporation from the snowpack in the open and under canopies of coniferous trees and aspen was measured and compared in the Wasatch Mountains of northeastern Utah. During clear winter days, the average evaporation in the open was 0.011 inch, under the aspen 0.008 inch, and under the conifers

0.005 inch. Condensation during the nighttime reduced the net evaporation loss to three-fourths of the total evaporation measured during the preceding day. Mean daily values of temperature, wind, and relative humidity accounted for 64 percent of the variation in snow evaporation. Contour trenching may influence snow accumulation on otherwise uniform slopes. This hypothesis was tested on a windswept-southwest exposure at 9,000-foot elevation with almost tundra-like conditions. Trenching increased snow accumulation slightly. More significant than increased water yields may be the influence of the redistributed snow on vegetation. The absence of frost in the trench bottom and the increased soil moisture in areas of snow accumulation should enhance plant growth.

(h) "A System for Automatically Recording Weight Changes in Sapling Trees," Harold F. Haupt and Bud L. Jeffers, USDA Forest Serv. Res. Note INT-71, 1967.

"Snow Catch by Conifer Crowns," Donald R. Satterlund and Harold F. Haupt, Water Resources Res. 3(4):1035-1039, 1967.

"Comparison of Gravimetric Measurements and Mass Transfer Computations of Snow Evaporation Beneath Selected Vegetation Canopies," Robert D. Doty and Robert S. Johnston, Proc. 37th Western Snow Conf., 1969.

"Influence of Contour Trenching on Snow Accumulation," Robert D. Doty, J. Soil & Water Conservation 25, 1970.

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, NORTH CENTRAL FOREST EXPERIMENT STATION, Folwell Avenue, St. Paul, Minnesota 55101. D. B. King, Director.

(3887)

WATERSHED MANAGEMENT RESEARCH IN NORTHERN MINNESOTA.

- (d) Experimental and field investigations; basic and applied research.
- (e) The project conducts research in the following major areas: (1) The surface and ground-water hydrology of small, forested bog watersheds -- measurements of rain, snow, runoff, bog water tables, and the deep regional ground-water system are carried out on six experimental bogs to determine their natural hydrology and contributions to runoff and ground water, (2) laboratory and field studies of the physical properties of organic soils and their influence on peatland hydrology, (3) evapotranspiration and microclimate relationships on peatlands, including energy balance factors, and (4) water quality relationships in bogs and swamps. The purpose of the project is to develop land management practices, through basic hydrologic studies, that will maintain and improve water yield from northern forested peatlands.
- (g) Seasonal water balance computations from several small peatland watersheds were comparable to potential evapotranspiration as computed by the Thornthwaite method. However, short-term computations during periods of low water tables were consistently less than calculated potential ET. Important physical characteristics of peat materials such as water retention, water yield coefficient, and hydraulic conductivity were related to degree of decomposition as measured by fiber content and bulk density. Present peat classification systems that estimate fiber content or bulk density thus relate significant information about the physical properties of various peat materials in the field.
- (h) "Evapotranspiration from Two Peatland Watersheds," Roger R. Bay, I.A.S.H. Publ. 78, Gen. Assembly of

Bern: 300-307, 1967.

"Physical Properties of Peats as Related to Degree of Decomposition," Don H. Boelter, Soil Sci. Soc. Amer. Proc. 33(4):606-609, 1969.

"Water Storage and Related Physical Characteristics of Four Mineral Soils in North-Central Minnesota," E. S. Verry, USDA Forest Serv. Res. Note NC-78, 4 p., 1969.

"Runoff from Small Peatland Watersheds," Roger R. Bay, J. Hydrol. 9: 90-102, 1969.

"Hydrologinen Tutkimus Yhdysvaltain Pohjoisosien Soila," Roger R. Bay, Suo 20(5): 81-85, 1969.

(3889)

WATERSHED MANAGEMENT RESEARCH IN THE DRIFTLESS AREA OF SOUTHWESTERN WISCONSIN.

(b) Some aspects of project in cooperation with Wisconsin Conservation Department.

(d) Field investigations; basic and applied research.

(e) Research is conducted on the influence of both natural and planted forests on runoff and erosion (particularly with regard to spring-thaw floods) and hydrologic effects of soil freezing. The study of forest-land gullies and the reduction of gully by spreading upland runoff into the lower lying forest zone is included. Overland flow is measured by flumes and recorders at 20 stations, either on natural runoff plots or small watersheds. Factors affecting springflow are also under study. Springflow is measured at 2 stations by weirs and recorders. In addition, a number of wells are measured, one with a water level recorder.

(g) Runoff studies showed that forest-covered watersheds produced overland flow only after heavy rains, and the amounts of flow and peak rates were low compared with those from openland watersheds. Peak flow rates from a major storm ranged from 64 millimeters per hour for tilled land to no flow for undisturbed forest. Peak rates from tilled land averaged 2.5 times those from meadow, and peak rates from meadow 1.4 times those from an abandoned field. Sediment yield was low for forest, abandoned field, and meadow, but high for tilled land and heavily grazed pasture. Neutron meter studies of soil water movement in deeply frozen soils showed that changes in soil water took place throughout most of the frost season. One series of data showed that water may infiltrate and percolate through more than 60 cm. of hard-frozen ground. However, frozen ground did impede percolation, causing a buildup of water in the frozen zone during spring melt. Although neutron readings increased at upper levels during the frost season, most of the increases could not be accounted for by decreases at lower levels. Thus, they appeared to result more from infiltration than from upward migration. A plastic tube, filled with a sand-fluorescein mixture, and inserted in the ground, proved to be a reliable indicator of frost depth. The readings were within ± 5 centimeters of true frost depth 95 percent of the time. A comparison of popular conceptions and scientific knowledge about the role of forests in the hydrologic cycle pointed up the disparity between the two.

(h) "Soil Water Movement as Affected by Deep Freezing," Richard S. Sartz, Soil Sci. Soc. Amer. Proc. 33(3): 333-337, 1969.

"Folklore and Bromides in Watershed Management," Richard S. Sartz, J. Forest. 67(6): 366-371, 1969.

"Interpreting Neutron Probe Readings in Frozen Soil," Richard S. Sartz, USDA Forest Serv. Res. Note NC-77, 4p., 1969.

"Effect of Watershed Cover on Overland Flow from a Major Storm in Southwestern Wisconsin," Rich-

ard S. Sartz, USDA Forest Serv. Res. Note NC-82, 4 p., 1969.

(3890)

WATERSHED MANAGEMENT RESEARCH IN LOWER MICHIGAN.

(d) Field investigation; basic and applied research.

(e) The major projects involved here deal with (1) ground water recharge and evapotranspiration of various cover types in deep sandy soil and (2) streambank erosion and sediment transport on trout streams. Ground water elevations are being measured at 162 wells, 11 of which are equipped with water level recorders. Fifty percent of the trees have been removed in strips in a 35-year old jack pine plantation to study changes in net water yield and in snowpacks. Snow studies are also being made in selectively thinned red pine plantations. Stream sediment budgets are being intensively measured on a trout stream having serious bank erosion. Bank profiles are being measured of one-fourth of the banks to obtain rates of recession and volumes of various sizes of sediments eroded. Total sediment discharge is measured over sills above, in the middle, and below the 20-mile test reach. Effects of sediment on bottom fauna and on trout spawning bed permeability are being studied.

(g) Total sediment load along a pool and riffle stream was found to increase 530 percent along a 26-mile reach, with most of the sediment originating from 200 eroding streambanks. Approximately 75 percent of the total sediment load is sand size, the same proportion as found in the eroding bank materials. Two-thirds of the sediment load moves as bedload through the sections of stream channel that have lowest gradients. Areas of sand streambed, where sediment exchange could occur between the bed and moving sediment, comprised 22 percent of the total streambed area. There is an annual cycle of changes in sediment storage on the streambed, with maximum volumes in storage during the spring high flow period and minimum volumes during late summer low flows.

Measures of water yield under strip-cut blocks of jack pine showed that the reduction in evaporative losses due to removing 50 percent of the trees was 4.2 inches in the first year after cutting, 2.4 inches the second year, and 2.0 inches in the third year. An alternative method of analysis, using finite-difference equations to solve for net ground-water accretion (gross recharge minus evaporative drain), showed similar differences in annual water yield. The numerical method indicated higher evaporative losses from shallow water-table aquifers. All estimates of annual water yields were lower than those computed by analysis of diurnal fluctuations in water table levels. Our previous estimates of water yields on shallow water table lands were probably high due to this error in measuring evaporative losses.

(h) "Stabilizing Eroding Streambanks in Sand Drift Areas of the Lake States," Edward A. Hansen, USDA Forest Serv. Res. Rep. NC-21, 12 p., 1968. "Relation of Snowpack Accumulation to Red Pine Stocking," Edward A. Hansen, USDA Forest Serv. Res. Note NC-85, 4 p., 1969.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, NORTH-EASTERN FOREST EXPERIMENT STATION, 6816 Market Street, Upper Darby, Pennsylvania 19082. R. D. Lane, Director.

The following projects are listed by title only; for more details see "Water Resources Research Catalog":

(067W)
FLOOD RUNOFF REDUCTION AND WATER YIELD IMPROVEMENT FROM THE GLACIATED MOUNTAIN AREAS OF NEW ENGLAND. (Durham, New Hampshire).

(068W)
FLOOD RUNOFF REDUCTION AND WATER YIELD IMPROVEMENT IN THE NORTHERN APPALACHIAN MOUNTAIN REGION. (Parsons, West Virginia).

(069W)
CORRELATION AND SYNTHESIS OF WATERSHED RESEARCH RESULTS, COOPERATIVE MUNICIPAL WATERSHED RESEARCH, AND URBAN AND SUBURBAN STUDIES OF TREES AND HUMAN ENVIRONMENT. (Upper Darby, Pennsylvania).

(070W)
EFFECTS OF DIFFERENT FOREST TYPES AND CONDITIONS ON STREAM REGIMEN AND WATER YIELDS. (Syracuse, New York).

(6972)
MANAGEMENT OF STORM RUNOFF.

(d) Experimental and field investigations; basic and applied research.

(e) Laboratory and field investigation of subsurface stormflow processes in forested soils leading to development of techniques for predicting and altering quantity and timing of this flow.

(f) Terminated June 30, 1970.

(g) Overwhelming importance of subsurface flow in contributing to stormflow from forested areas was demonstrated and documented. The importance of macro-pores (e.g., old root channels) in transmitting water was shown and techniques for soil-sampling to measure macro-pores were developed. Supporting laboratory studies showed reorientation of soil particles and increase in soil density close to the soil-root channel interface.

(h) "Storm Runoff from Forested Catchments by Subsurface Routes," R. Z. Whippley, Proc. of the Leningrad Symp. -- Aug. 1967 -- Floods and Their Computation, pp. 773-779, 1969. Int. Assoc. Sci. Hydrology.

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION, P. O. Box 3141, Portland, Oregon 97208. Philip A. Briegleb, Director.

(4757)
WATER YIELD AND EROSION, WENATCHEE, WASHINGTON.

(d) Field investigations; basic and applied research.

(e) The objectives of the project are to generate information on the relations of moisture disposition and use, and incidence of soil erosion, in forest and range environments to climatic characteristics, vegetative types, soil types, topography, and land uses; and to devise management techniques for ensuring maximum streamflow and minimum erosion and sedimentation in the mid-Columbia River Basin in eastern Oregon and Washington. Studies related to erosion reduction include: Characteristics of soil related to erodibility; effects of climate, vegetation and parent material on soil development, characteristics of forest humus types; and physical control of erosion by increasing density of vegeta-

tion. Factors influencing receipt, disposition, and use of water include: Head and moisture flux, and partitioning of the solar energy balance over forest canopies; seasonal soil moisture depletion under a lodgepole pine forest; moisture use requirements of six principal conifers; effects of silvicultural treatments, including precommercial thinning and harvest cuttings, on water yields; disposition of intercepted snow and rime ice.

(g) Summer soil moisture regime has been monitored under a lodgepole pine stand for a number of years. Significant potential savings of soil moisture in conditions prevalent in the eastern Cascades were found to result from a clearcutting treatment.

Horizontally intercepted precipitation in the form of rime ice during winter was studied in a lodgepole pine stand. Results show that this generally unmeasured supplemental precipitation amounts to 0.05 to 0.06 inch moisture equivalent per day and could contribute as much as 3 to 4 inches total moisture in an entire winter.

For this latter study an unattended time-lapse camera provided the main record. Methods of digitizing climatological data for portrayal with time-lapse camera were developed. The methods were successfully applied to temperature, dew-point, and wind.

Tracing movement and dispersion of soil-sized fluorescent particles is a promising method for detecting and describing soil erosion. Actively eroding and stable sites are readily identified; size of particles in motion and causal agents may also be inferred. Equipment is simple to operate, and no health hazards are involved.

Differences in erosion potential develop on soils derived from similar parent materials. Certain of these differences are attributed to production and incorporation of litter in soil. Identifying erosion-indicating features enhances decision making in watershed management.

An air pycnometer was developed for special application to forest and range soils. This device accurately assesses total porosity, macro- and micropore space, and bulk density from a single sample.

(h) "Soil-Moisture Depletion by a Central Washington Lodgepole Pine Stand," H. G. Herring, Northwest Sci. 42: 1-4, 1968.

"Rime and Hoarfrost in Upper-Slope Forests of Eastern Washington," H. W. Berndt and W. B. Fowler, J. For. 67(2): 92-95, 1969.

"A Digital Temperature Monitor for Photorecording," William B. Fowler, U. S. Forest Serv. Res. Note PNW-95, 7 pp., 1969.

"A Digital Indicator for Maximum Windspeeds," William B. Fowler, U. S. Forest Serv. Res. Note PNW-98, 4 pp., 1969.

"Stomatal Closure in Conifer Seedlings in Response to Leaf Moisture Stress," William Lopushinsky, Bot. Gaz. 130(4): 258-263, 1969.

"A Portable Apparatus for Estimating Stomatal Aperture in Conifers," William Lopushinsky, Pacific NW. For. and Range Expt. Sta., 7 pp., 1969.

"Fluorescent Materials Index Soil Movements," W. B. Fowler and H. W. Berndt, U. S. Forest Serv. Res. Note PNW-107, 7 pp., 1969.

"Soil Erosion in Relation to Properties of Eastern and Western Washington Forest Soils," A. N. Balci, Soil Sci. Soc. Amer. Proc. 32(3): 430-432, 1968.

"Some Autecological Characteristics of Elk Sedge," G. O. Klock, U. S. Forest Serv. Res. Note PNW-106, 5 pp., 1969.

"An Air Pycnometer for Forest and Range Soils," David D. Wooldridge, Pacific NW. Forest and Range

(4758)

SOIL STABILITY AND STREAMFLOW.

- (b) Laboratory project with some phases in cooperation with City of Portland, Bureau of Water Works and Oregon State University.
- (d) Field investigations; basic and applied research.
- (e) The objectives of this project are to determine how logging methods, road construction, and other forest management practices can be improved to curtail erosion, protect fish habitat, maintain water quality, and regulate quantity and timing of runoff. Field research is conducted on experimental watersheds at three field locations in the Cascade Range of western Oregon: Bull Run Watershed (domestic supply area for Portland), H. J. Andrews Experimental Forest, and South Umpqua Experimental Forest. Studies are confined to two forest types representing major segments of the remaining old-growth forest of the Pacific Northwest: (1) Douglas-fir, western hemlock, western redcedar, and (2) Douglas-fir, sugar pine. Precipitation, runoff, erosion, and soil moisture are studied in undisturbed stands and following several methods of logging. Support laboratory facilities are available at the Forestry Sciences Laboratory in Corvallis. Studies are grouped in four categories: (1) Soil stability, which includes surface erosion on undisturbed soil surfaces, mass soil erosion, and stabilization of disturbed soils by vegetative and mechanical methods. (2) Water quality, which involves determination of changes due to current forest management practices, significance of these changes, and improved practices to protect the water quality. (3) Stream hydrology, including water quantity and timing. (4) Stream habitat. Information in categories 1, 2, and 3 is basis for study of the relationship of logging and roadbuilding to stream habitat and the fishery resource.
- (g) Recent research results from small experimental watersheds show that after complete clearcutting, annual streamflow may increase as much as 18 inches during the years immediately following logging and burning. Minimum streamflow also increased significantly with larger increases following heavier cutting. Extensive logging may increase early winter seasons stormflow but probably does not alter streamflows from major midwinter storms. Considerable damage from severe winter storms results primarily from soil instability. Surface erosion may be a serious problem in local areas of the Pacific Northwest, but massive soil movements are more common to the region. When stream surfaces are exposed by logging, maximum stream temperatures may increase. The first year after slash was burned on a 237-acre clearcut watershed in the Cascade Range of Oregon, average maximum water temperatures increased 13°, 14°, and 12°F during June, July, and August. A maximum stream temperature of 75°F persisted for 3 hours on a day in July. Soils on three small experimental watersheds were found to permit rapid rates of water movement as a result of their porous nature. The importance of stone content as a hydrologic factor required some revision of the original soil classification scheme before water storage capacity relationships could be correctly assessed.
- (h) "Influence of Forest Management Practices," Jack Rothacher, In Water and Environmental Quality, Semn. WR008.67, Water Resources Res. Inst., Oreg. State Univ., pp. 25-31, Jan. 1968. "Flood Damage in the National Forests of Region

- 6," Jack S. Rothacher and Thomas B. Glazebrook, Pacific Northwest Forest & Range Exp. Sta., USDA Forest Serv., 20 pp., illus., 1968. "Natural Filtering of Suspended Soil by a Stream at Low Flow," Norman H. Miner, U. S. Forest Serv. Res. Note PNW-88, 4 pp., illus., Sept. 1968. "Vegetation of Oregon and Washington," Jerry F. Franklin and C. T. Dyrness, U. S. Forest Serv. Res. Pap. PNW-80, 216 pp., illus., 1969. "Early Plant Succession Following Logging and Slash Burning in *Pseudotsuga* Forests in Oregon," (Abstr.), C. T. Dyrness, XI Int. Bot. Congr. Abstracts of Papers, Seattle, Wash., p. 50, Aug.-Sept. 1969. "Increases in Maximum Stream Temperatures After Slash Burning in a Small Experimental Watershed," Al Levno and Jack Rothacher, U. S. Forest Serv. Res. Note PNW-110, 7 pp., illus., Aug. 1969. "Hydrologic Properties of Soils on Three Small Watersheds in the Western Cascades of Oregon," C. T. Dyrness, U. S. Forest Serv. Res. Note PNW-11, 17 pp., illus., Sept. 1969.

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION,
P. O. Box 245, 1960 Addison Street, Berkeley, California 94701. Robert D. McCulley, Director.

(4996)

WATER YIELD IMPROVEMENT, CONIFER ZONE.

- (b) Cooperator: U. S. Atomic Energy Commission.
- (c) Dr. James L. Smith, Project Leader, Water Yield Improvement, Conifer Zone.
- (d) Experimental; field investigation; basic and applied research.
- (e) The objective of this project is to determine methodology for increasing water yield and changing the timing of water delivery by vegetation manipulation, by evaporation suppressants, etc. Its area of interest is confined to the snowpack zone of the Sierra Nevada of California. Present studies emphasize development of methods for management of high elevation snowpacks for yield and control of water; the effects of timber cutting upon soil moisture losses and snow accumulation and melt; and the evapotranspiration from various sites-species combinations. (See 1968 issue for laboratory details -- ed.) In the headwaters of the Feather River a practical sized logging is being tested for snow accumulation and melt effects. Gamma and neutron probes are being tested for measuring hydrologic characteristics of snowpacks. Evaporation suppressants are being tested for reduction of such losses from snowpacks.
- (g) A snowgauge has been developed which can measure snow density in 1/2-inch vertical increments from the soil to the snowpack surface. The system is based on commercially available gamma transmission equipment. The number of unattenuated gamma photons which pass through the snow from a source to a detector is a measure of snow density. Regression analysis indicated that snow density may be determined with an error of 0.015 gm cm⁻³ in the density range 0.001 to 0.686 gm cm⁻³. Output of the nuclear scaling equipment may be converted to direct density readings by an analog signal conditioner and recorded by a chart recorder or digitized and printed by a digital recorder. The process is covered by a Government Patent. Snowpack hydrology was studied with the gage. Artificial and natural rain on-snow events were investigated to determine the water holding capacity of snow. Snow in a mature condition

absorbed and retained from 0.04 to 0.08 gm cm⁻³ of liquid water in the ice matrix. In contrast, snow in an early winter condition may absorb and retain 0.10 gm cm⁻³ of liquid water without drainage. Melt in the late spring season increases the density of the lower portion of the snowpack temporarily. Drainage is rapid after the water holding capacity of the snow is satisfied. These studies are continuing.

The snow gage was used as a standard for a study of the energy balance components of the snow surface. Measurements of net radiation, specific humidity, air movement and air temperature one meter above the snow surface could be used to predict accumulative snow melt and evaporation from a snowpack on a seasonal basis. Energy balance equations were considered a successful method to predict snow melt. This is a continuing study.

Snow evaporation was measured under a wide range of conditions of humidity, wind, and temperature in a controlled environment room. Humidity ranged from 20 to 80 percent, wind from 0 to 20 miles per hour, and temperature from 25 to 50°F. Correlations with wind speed and water vapor pressure deficit yielded correlation coefficients as high as 0.82. Employing a mass transfer equation which included the distance to the up-wind vegetation boundary yielded correlation coefficients greater than 0.9 at most temperatures. This study has been completed. In a companion experiment hexadecanal was shown to be an acceptable evaporation retardant, especially in exposed sites. Studies with C¹⁴ tagged material showed that hexadecanal migration was practically nonexistent if the hexadecanal suspension was allowed to age one week before application. The chemical reduces evaporative losses by about 90 percent. This study has been closed.

A study has been completed which was designed to develop predictive equations for consumptive water use from forested watersheds. The studies were carried out on watersheds from 0.27 to 0.9 square mile in area over a 10-year period. The studies were an attempt to estimate how water yields would be changed by vegetation manipulation practices. Measured and predicted water use averaged 25.23-inches per year and ranged from 20.91 to 27.26-inches. In addition, a precipitation "carryover" effect was noted which influenced water yield for three subsequent years.

- (b) "Use of Radioisotope to Trace Water Movement in Coniferous Trees," P. W. Owston and J. L. Smith, 1968, Amer. Jour. Bot. 55(6):728-9.
- "Development of Some Radioisotope Procedures for Measuring Water Movement in Trees," P. W. Owston, J. L. Smith, and H. G. Halverson, 1969. U. S. Atomic Energy Comm., Div. Tech. Information, TID-25736, 55 pp. illus. Washington, D. C.
- "Snow Research in the Sierra Nevada, California," J. L. Smith, 1968. Forest Service USDA, Pacific Southwest Forest and Range Exp. Sta., unnumbered publication.
- "Hydrology of Snow Profiles Obtained with the Profiling Snow Gage," J. L. Smith and H. G. Halverson, 1969. Western Snow Conf. Proc. 37:41-48.
- "The Profiling Snow Gage and Its Utility in Water Supply Forecasting," J. L. Smith, H. G. Halverson, and R. A. Jones, 1969, Trans. Amer. Nuclear Soc. 12(2):500-501.

(4997)

HYDROLOGIC ANALYSIS METHODS.

- (b) Cooperators are: State of California, Dept. of Water Resources; Univ. of California; State of Hawaii, Div. of Forestry.
 - (c) Mr. Henry W. Anderson, Project Leader.
 - (d) Experimental and theoretical; basic and applied research.
 - (e) The objective is through analytical modeling to advance the state of knowledge of watershed hydrology and sedimentation, and particularly, knowledge of the relationship of watershed management and other hydrologic processes at the water sources to water yield, floods, sedimentation, and water quality delivered from wildland watersheds.
 - (g) Computer programs have been developed which will allow the individual researcher, forester, or engineer to classify, store, and retrieve literature, abstracts, meeting notes, etc.
- A new procedure is recommended for use in hydrologic analysis. "Antifactor analysis" resulting from work done with reduced rank regression prediction is defined as a useful tool for certain types of hydrologic research. Antifactor analysis is a numerical screening and modeling procedure based on criteria and expectations different from classical factor analysis. Classical factor analysis is not considered useful in hydrologic studies since in hydrology there are rarely large samples taken from a homogeneous population. Furthermore, measurement errors on hydrologic variables tend to be much smaller than those in typical psychometric studies. To make classical factor analysis work with hydrologic data, it was necessary either to define the factors in nonmetric terms or to define the factors in terms of the variables and accept the idea that factorial invariance cannot be obtained. Antifactor analysis can be used in solving complex prediction problems and can be expected to yield equations which outperform others when used in tests with independent samples.
- To get long-term estimates of deposition in reservoirs in northern California from short-term records, allowance was made for the differences in sediment potential among widely different periods of measurement. Streamflow records for a 75 year period, 1891 to 1965, for 18 widely distributed streamflow measurement stations were used. One index of the relative sediment potential for a year was the product of the maximum daily flow times the total volume of flow, divided by the long-term average flow for the watershed. A simple program filled in the missing years from adjacent watersheds; a double-massed test of each watershed against the mean of eight to 10 streams tested for consistency of the record, and another program selected the streamflow index for each watershed, associated it with a period of deposition, and computed the relative sediment potential for the watershed and period.
- Appraisals of time variations in sediment potential may permit us to better-evaluate the causes of watershed differences in sediment production and perhaps also give us some indication of what our short-term experimental results really represent.
- (h) "Computer Documentation and Retrieval of Hydrologic Information for Small Groups or Individuals," Henry W. Anderson and Theodore B. Yerke, Int. Ass. Sci. Hydrol. Publ. 81:555-560, 1968.
 - "Factor Analysis in Hydrology--An Agnostic View," James R. Wallis, Water Resources Res., 4(3), 521-527, 1968.
 - "Snowpack Management," Henry W. Anderson, Oregon State Univ. Water Resources Inst. Seminar, WR 011.69, 27-40, 1969.

FLOOD AND SEDIMENT REDUCTION IN THE CONIFER ZONE OF CALIFORNIA.

- (b) Cooperators are: Calif. Div. of Forestry; East Bay Municipal Utilities District; Calif. Dept. of Fish and Game; Humboldt State College.
 - (c) Dr. Jay S. Krammes, Project Leader, Flood and Sediment Reduction, Pacific Southwest Forest and Range Expt. Sta. (Arcata).
 - (d) Experimental; field investigations; basic and applied research.
 - (e) This project conducts basic studies of forest hydrology which will suggest methods of land management for improving water quality, maintaining fish habitat, preventing floods and controlling sediment in the commercial timber zones of California. A study of soil moisture depletion in the Sierra Nevada which is nearing completion concerns the magnitude of soil moisture storage and depletion under different stand and timber cutting intensities. Because soil creep and landslides are prevalent in the zone, a study of gravitational mass movement will form an effort to develop the means of estimating the consequences of mass movement in terms of sedimentation. The ultimate objective is to develop the means of predicting the role of land management practices, such as logging and road building in initiating or accelerating mass movement.
 - (g) Floods from streams flowing to the Pacific cause an average annual damage of more than \$520 per square mile. More than half of the total damage occurs in small watersheds--those with areas of less than 390 square miles. Since almost all the flood waters originate in wildland areas, it is possible that this problem may be moderated by management of small, wildland watersheds. Calibration of streamflow in two small watersheds (about 1200 acres each) of Caspar Creek is now completed. These watersheds are being used to determine the effect of redwood-Douglas-fir logging practices on streamflow and sediment production. At this time the effects of road construction are being evaluated. This research is part of a cooperative study with the State of California.
- Mass erosion processes, particularly landslides and soil creep, may account for much of the sediment reaching streams. Five years of creep observations indicate that soil creep is proceeding at a very rapid rate within the California coast range. These creep data are the most extensive, detailed, and accurate data available on the rates and trajectories of natural soil creep. A lateral creep rate of 1/4 inch per year involving an 8-foot thick section of soil (a conservative estimate for the coast ranges of California) will annually supply one ton of sediment per 50 foot of stream reach. Areal densities of streams that are subject of soil creep typically range between 2 to 3-1/2 linear miles of course per square mile.
- (h) "Soil Moisture Depletion Patterns Around Scattered Trees," Robert R. Ziemer, U. S. Forest Service Research Note PSW-166, 13 pp., 1968.
 - "Nicasio Hidden Valley in Transition," Robert Twiss, David Streatfield, Eugene Kojan, Arthur W. Magill, Marin County Planning Department Civic Center, San Rafael, Calif., 50 pp., 1968.

FLOOD AND SEDIMENT REDUCTION FROM STEEP UNSTABLE BRUSHLAND OF THE SOUTHWEST.

- (b) Cooperators: California Div. of Forestry, Los Angeles County Flood Control District; Los Angeles County Fire Dept., Univ. of California, Berkeley, Los Angeles, and Riverside; Angeles Natl. Forest.
 - (c) Mr. Raymond M. Rice, Project Leader, Pacific Southwest Forest and Range Expt. Sta., 110 North Wabash Ave., Glendora, Calif.
 - (d) Experimental; field investigations; basic and applied research.
 - (e) Purposes are (1) to determine how watersheds function, what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, geology, and topography, and (2) to evaluate the effect of various land management practices upon runoff and erosion and to develop land treatments - especially those aimed at reducing post-fire runoff and erosion.
 - (g) Project scientists have identified fire-induced hydrophobic soil as a cause of excessive erosion following brush fires. Laboratory studies are investigating the physical properties of hydrophobic agents. Field plots show 35-40 percent average reduction in overland flow and erosion. However, the one attempt to use a wetting agent treatment on a large area was not successful. The increase in soil slip erosion due to converting steep slopes from brush to grass on the San Simas Experimental Forest has been measured following two major storms. The storm of 1966 had about a 10-year return period. The storm of 1969 had a return period of about 50-years. In the first event grass areas produced 7.4 times as much erosion. The absolute difference in erosion was 135 cubic meters per hectare in 1966 and 546 per hectare in 1969. In 1966 only slopes steeper than 80 percent produced soil slips. In 1969 the threshold had been reduced to 60 percent. Investigation into the utility of multivariate statistical methods for predicting flood hydrographs revealed that a canonical correlation solution is equivalent to equal number of multiple regression equations using the same variables.
 - (h) Copies can be obtained from: Pacific Southwest Forest and Range Experiment Station, Dept. of Agriculture, U. S. Forest Service, P. O. Box 245, Berkeley, California 94701.
- "Soil Slippage: An Indicator of Slope Instability on Chaparral Watersheds of Southern California," Robert G. Bailey and Raymond M. Rice, 1969. The Professional Geographer 21(3): 172-177.
- "The Relationship Between Heat Treatment and Water Repellency in Soils," Leonard F. DeBano, 1969. Symp. on Water-Repellent Soils Proc., Univ. of Calif. Riverside, May 6-10, 1968, pp. 265-279.
- "Water Repellent Soils: A Worldwide Concern in Management of Soil and Vegetation," L. B. DeBano, 1969. Agric. Sci. Rev. 7(2): 11-18.
- "Soil Wettability and Wetting Agents - Our Current Knowledge of the Problem," Leonard F. DeBano, 1967. U. S. Forest Serv. Res. Paper PSW-43, Pacific SW. Forest & Range Exp. Sta., Berkeley, Calif., 13pp., illus.
- "Soil Slips Related to Vegetation, Topography, and Soil in Southern California," Raymond M. Rice, Edward S. Corbett, and Robert G. Bailey, 1969, Water Resources Research, 5(3): 647-659.
- "Multivariate Methods Useful in Hydrology," Raymond M. Rice, 1967. Proc. Int. Hydrol. Symp., Ft. Collins, Colo., Sept. 6-8, 1967. Vol. 1, pp. 471-478.

(5001)

WATERSHED MANAGEMENT RESEARCH IN HAWAII.

- (b) Cooperators: State of Hawaii, Dept. of Land and Natural Resources, Div. of Forestry.
- (c) Mr. Robert E. Nelson, Director, Institute of Pacific Islands Forestry, 530 South Hotel Street, Honolulu, Hawaii 96813.
- (d) Experimental; field investigations; basic and applied research.
- (e) The objective is to develop a hydrological and meteorological base in Hawaii's wildland watersheds that will suggest methods of land management for maintaining or improving water yield and water quality and minimizing soil erosion and sedimentation; to obtain adequate understanding of the processes of receiving and discharging water and being able to predict the effects of a wide span of forest land management practices upon water yield and water control; such studies are to suggest ways to manage watersheds that will (1) assure the continued protection of watersheds; (2) improve the distribution of the water yield by modifying the balance between the ground water recharge and surface waterflow; (3) increase water yields by decreasing evapotranspiration losses; and (4) minimize flood runoff and sedimentation. Honolulu is the work center. Principal studies are determining soil hydrologic characteristics; fog drip phenomena, evapotranspiration from several selected wildland vegetation types, and rainfall interception in different forest types.
- (g) Converting forest to other uses causes modification of soil hydrologic characteristics--greatly decreasing pore space and decreasing infiltration capacity. Surface clouds (fogs) are common but fog drip, if it occurs, is of very small magnitude in forests on the west slope of Haleakala, Maui.
- (h) Recent publications available from the Institute of Pacific Islands Forestry, 530 South Hotel Street, Honolulu, Hawaii 96813:
"Photographic Interpretation of Canopy Density--A Different Approach," William S. Null, J. Forestry 67(3): 175-177, illus. 1969.
"Vegetation Recovering - Little Erosion on Hanalei Watershed After Fire," Hulton B. Wood, Robert A. Merriam, and Thomas H. Schubert, U. S. Forest Serv. Res. Note PSW-191, 1969.

(7000)

WATERSHED SYSTEMS DEVELOPMENT UNIT.

- (b) Division of Watershed Management, U. S. Forest Service, National Forest System.
- (c) Donald W. Willen, Acting Project Leader, Watershed Systems Development Unit.
- (d) Theoretical; developmental, basic and applied research.
- (e) The objective of this unit is twofold: (1) the development of a systems approach to the resource management of National Forest land; and, (2) the development of analysis tools through the use of computers to solve day-to-day, on the ground problems in watershed management. The basic nature of this work unit is to provide consulting training, and computer analysis services to the water resource land managers of the National Forest System. Resource analysis tools are developed, and watershed management research results are blended with the water and related resource problems of the land manager.
- (g) Since the formation of this work unit approximately four years ago, about 20 computer programs are operational, or nearly so, to reduce streamflow, precipitation, temperature, wind movement, etc., data and to analyze hydrometeorological data for determining water balances, erosion and sedimenta-

tion amounts, etc. These programs have been designed for and are particularly useful to water resource managers in the National Forest System. In response to the Colorado River Basin Project Act of 1968 (P.L. 90-537) a reconnaissance survey has been completed by the National Forest system in which this unit was an integral part of the team and provided the necessary consulting services and computer programs to accomplish the task. The objective of this study was to determine the capability of improving the water resources (yield) of the Pacific Southwest Service area. This area encompasses the Colorado River Basin and a large portion of California. At present this unit is involved in the detailed planning and systems design of the second phase of the above study, which is concerned with the resource capability and management alternatives of this service area. A user's guide has been partially completed which outlines a systems approach to resource management. Operations research tools such as linear programming, simulation techniques for the analysis of hydrologic information, and a data storage and retrieval system are in various stages of completion.

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION, 240 W. Prospect Street, Fort Collins, Colorado 80521. Raymond Price, Director.

(037W)

WATER YIELD IMPROVEMENT IN SNOWPACK TIMBER ZONE, AND REDUCTION OF RUNOFF FROM RANGELANDS IN THE CENTRAL ROCKY MOUNTAINS.

For summary, see Water Resources Research Catalog, Vol. 4, 3.0143.

(074W)

WATERSHED MANAGEMENT RESEARCH (CHAPARRAL), TEMPE, ARIZONA (formerly 657A).

For summary, see Water Resources Research Catalog, Vol. 4, 4.0006.

(075W)

WATERSHED MANAGEMENT RESEARCH, ALBUQUERQUE, NEW MEXICO (formerly 1969).

For summary, see Water Resources Research Catalog, Vol. 4, 2.0234 and 4.0175.

(657B)

WATERSHED MANAGEMENT RESEARCH (RIPARIAN), TEMPE, ARIZONA.

- (d) Experimental; basic and applied research.
- (e) To determine the amount of water used by phreatophytic vegetation (water-loving plants) and to develop methods for reducing water use or for replacing present species with more useful plants. Ecological studies of tamarisk and other phreatophytes are continuing.
- (g) The environmental parameters conducive to internal plant-water movement are being studied in mesquite (*Prosopis juliflora*) including the effects rising water tables have on cooling capacity of leaves and on sap velocity. Vast acreages of mesquite in the Southwest are potential sites for watershed management; thus determination of ground water use by the species is important. The pressure bomb technique proved to be a useful indicator of changes in plant-moisture stress following partial crown removal of birchleaf mountainmahogany (*Cercocarpus betuloides*). Approximately 40 percent crown removal is necessary before plant moisture tensions are significantly

changed, and, by inference, soil moisture conditions surrounding plant roots.

- (h) "Perpetual Succession of Stream-Channel Vegetation in a Semiarid Region," C. J. Campbell and Win Green, J. of Ariz. Acad. Sci. 5(2):86-98, 1968. "Ecological Implications of Riparian Vegetation Management in the Southwest," C. J. Campbell, J. Soil and Water Conserv. 25(2), 1970.

(657C)

WATERSHED MANAGEMENT RESEARCH (PINE-FIR), TEMPE, ARIZONA.

- (d) Experimental; basic and applied research.

- (e) Field and laboratory project to study: Effect of timber and grassland manipulations on water yield improvement; effect of changes in forest vegetation on evapotranspiration, radiation, and snow-melt and accumulation; and determination of the process of infiltration, retention and movement of water in soils, and how frost affects both saturated and unsaturated water flow.

At Sierra Ancha Experimental Forest in central Arizona three pine-fir watersheds (Workman Creek, elev. 7,000 ft.) are currently under experimental treatments. In eastern Arizona two ponderosa pine watersheds (Castle Creek, elev. 8,000 ft.), four mixed-conifer watersheds (Willow-Thomas, elev. 9,200 ft.), and two high elevation grassland watersheds (Seven Springs, elev. 9,300 ft.) are in stages of calibration or treatment. Plot studies include measurements of microclimate, radiation, frost, and snow accumulation and melt. Treatment of Castle Creek watersheds was completed. The plan has been to place five-sixths of the watershed in the best growing condition possible for existing ponderosa pine by removing mature and overmature trees and trees growing in crowded conditions. The remaining one-sixth of the area was clear cut in blocks fitted to existing stands of overmature and mature tree classes.

- (g) Water yield from the treated West Fork of Castle Creek indicates significant water yield measures for the first 2 years after treatment. The 10 years of pretreatment data (1955 to 1965) describe a regression that is being used as a pre-treatment base for determining post-treatment effects on water yields.

The post-treatment years approached opposite extremes, 1967 with less than 1-inch water yield, 1968 with more than 7 inches. Comparison of these 2 years with the pretreatment regression indicates approximately 1/3-inch increase in 1967 and more than 1 inch annual increase during 1968. A covariance analysis indicates statistical significance. A significant difference in slope of the two regression lines is apparent, a combination of an additive and multiplicative model. A certain degree of logic is apparent in this type of model. The increase was smallest during 1967, the year of less than average streamflow, and highest during 1968, the year of higher than average streamflow. It should be pointed out that this report covers only 1 year of complete treatment data (1968) and 1 year when treatment was not entirely completed (1967). Final indications of treatment effects will require additional intermediate points. There is an indication, however, that the treatment as applied to the West Fork of Castle Creek--clearcutting approximately one-sixth of the watershed and placing the remaining five-sixths in the best growing condition possible--has significantly increased water yields.

(2658)

WATER YIELD IMPROVEMENT IN THE BLACK HILLS.

- (d) Experimental; basic and applied research.

- (e) Experimental study of geologic and associated site factors to improve the basis for prediction of watershed behavior; soil moisture in relation to forest stand characteristics to provide criteria for design of forest stand manipulation to improve water yield; effects of valley bottom grassland uses on stream channels and flow characteristics to improve the basis for management design.

- (g) Differences in yield characteristics of three small mountain watersheds match with properties measured or inferred from geophysical measurements (refraction seismograph and electrical resistivity) and morphometric analyses. The watershed with the least volume of porous mantle and the highest frequency of steep slopes also has the least storage capacity and the highest frequency of low or zero flow.

Gross rainfall is the primary determinant of both throughfall and stemflow in second-growth pine. However, it has also been found that throughfall can be adjusted for canopy density, and stemflow for tree size (d.b.h.). Results demonstrate how two such relationships could be combined to estimate or adjust net rainfall for different stand densities.

Seeded grasses in combination with native vegetation reduced summer storm runoff and soil erosion to tolerable limits within one to four years on a Black Hills forest burn. Trends were best defined by relationship to an excess rainfall factor. About 60 percent ground cover was found necessary for soil stability. Chance is slight that ground cover could have reached this density in four years without seeding.

- (h) "Soil-Moisture Trends After Thinning and Clear-cutting in a Second-Growth Pine Stand in the Black Hills," Howard K. Orr, USDA Forest Serv. Res. Note RM-99, 8 pp., 1968.

(3569)

WATERSHED MANAGEMENT RESEARCH, LARAMIE, WYOMING.

- (b) Laboratory project and Bureau of Land Management.

- (d) Field investigation; applied research.

- (e) Water yield characteristics of big-sagebrush lands are being studied on plots and gaged watersheds, and hydrologic effects of control measures are being determined. Methods for increasing snow accumulation in windswept areas are also being developed and tested.

- (h) "Physical and Economic Design Criteria for Induced Snow Accumulation Projects," R. D. Tabler, Water Resources Res. 4(3):513-519, 1968.

"Soil Moisture Response to Spraying Big Sagebrush With 2,4-D," R. D. Tabler, J. Range Manage. 21(1):12-15, 1968.

"Hydrologic Properties of Peat from a Wyoming Mountain Bog," David L. Sturges, Soil Sci. 106(4):262-264, 1968.

"Gross Alpha and Beta Radiation in Waters at a Wyoming Mountain Bog," David L. Sturges, Water Resources Res. 4(1):159-162, 1968.

"Evapotranspiration at a Wyoming Mountain Bog," David L. Sturges, J. Soil and Water Conserv. 23(1):23-25, 1968.

(3895)

WATER YIELD IMPROVEMENT IN ALPINE AREAS AND AVALANCHE PREDICTION AND PREVENTION.

- (d) Experimental and field investigation; applied research.

- (e) To determine methods for controlling the deposition of snow in alpine areas in order to increase

- summer streamflow from late-lying snowfields. To reduce danger from snow avalanches to winter sports areas, highways, mining operation, and homes by improving the evaluation and forecasting of avalanche hazard and developing methods of stabilizing the snow cover on mountain slopes.
- (g) Studies of many avalanches in Colorado showed that 80 percent of them were of the slab type with soft slab more frequent than hard. Comparison of snow on the ground in a sheltered test field and on nearby avalanche slopes showed snow depth, grain shape, and snow strength to be similar in the bottom layer of snow at the two sites. The snow in middle layers was stronger and denser on the slopes than in the test field. A control curve based on new snow weight and storm duration was developed for central Colorado. A classification scheme for snow on the ground was developed, based on the processes that cause changes in the deposited snow. A network of snow, weather, and avalanche reporting stations was set up in Western United States to aid in evaluating avalanche hazard buildup at these sites. A photoelectric device to count individual snow particles was designed, built, and field tested. Particle count and speed could be determined in the field. Slab avalanches were shown to release by brittle fracture. The Griffith fracture criterion and stress concentration theory indicate snow may be thought of as a macroscopic, molecular model of glass.
- (h) "Snow Cover and Avalanches in the High Alpine Zone of Western United States," Arthur Judson, Physics of Snow and Ice, Proc. Int. Conf. Low Temp. Sci., Hirobumi Oura (ed.) Vol. 1, Part 2, pp. 1151-1168, 1967.
- "A Process-Oriented Classification for Snow on the Ground," Richard Sommerfeld, Proc. 6th Conf. on Snow and Ice, Nat. Res. Council of Canada, October 1969.
- "A Pilot Study of Weather, Snow and Avalanche Reporting for Western United States," Arthur Judson, Proc. 6th Conf. on Snow and Ice, Nat. Res. Council of Canada, Oct. 1969.
- "Classification Outline for Snow on the Ground," Richard Sommerfeld, USDA Forest Serv. Res. Paper RM-48, 24 pp., 1969.
- "The Role of Stress Concentration in Slab Avalanche Release," Richard Sommerfeld, J. Glaciology 8(54): 451-462, 1969.
- "A Photoelectric Snow Particle Counter," R. A. Schmidt and Richard Sommerfeld, Proc. 37th Western Snow Conf., Salt Lake City, pp. 88-91, 1969.
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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE,
SOUTHEASTERN FOREST EXPERIMENT STATION, P. O. Box
2570, Asheville, North Carolina 28802. Walter M.
Zillgitt, Director.

- (380)
 WATER RESOURCE AND WATERSHED MANAGEMENT RESEARCH.
- (d) Experimental; basic and applied research.
- (e) Basic research into forest hydrologic processes governing the disposition of precipitation on forest lands of the southeastern United States. Demonstrations of several cover types and land management practices and their effect upon the amount, quality, and timing of water yield. Development of watershed management methods pertinent to the region including pilot testing, cooperative trials, and demonstrations of these methods. The work is centered at the 5,600-acre Coweeta Hydrologic Laboratory in the mountains of western North Carolina near Franklin. Located in the zone of maximum precipitation in the eastern United States, the research area receives an average of 80 inches of precipitation each year, mostly coming as rain in about 100 separate climatic events. (See 1968 issue for laboratory details -- ed.) Research studies include: (1) forest treatment effects on water yield; (2) the hydrology of mountain unit watersheds under several cover types; (3) movement and storage of soil water on steep slopes; (4) predicting soil moisture in steep terrain for hydrologic purposes; (5) water quality of mountain watersheds as related to land use; (6) predicting peak discharge from small forested watersheds; (7) the effect of forest cutting on the flow frequency distribution; (8) structural descriptions of plant communities as related to water yield; (9) interception characteristics of forest stands; (10) effect of forest cover and mountain physiography on the radiant energy balance; (11) heat and vapor transfer processes over steep forested slopes; (12) mechanizing hydrologic data collection and processing; and (13) pilot testing multiple use of forest for water, timber, recreation, and wildlife on a 365-acre watershed.
- (g) Mixed mature hardwoods were cleared from two Southern Appalachian experimental watersheds, and the areas were planted with eastern white pine in 1956-1957. Once the pine crowns began to close, streamflow steadily declined at a rate of 1 to 2 inches per year. By 1967, water yield was 3.7 inches less from a 10-year old pine stand on a south-facing watershed than expected water yield from the original hardwood forest. Most of the water yield reduction occurred during the dormant season and was attributed mainly to greater interception loss from white pine than from hardwoods. Because interception differences increase as white pine matures, an even greater reduction in streamflow is expected. Compatibility of forest management practices on a 356-acre Southern Appalachian watershed was examined in a unique experiment to determine the feasibility of intensive management for wood, water, wildlife, and recreation. An efficient and stable access system was stressed, and the effect of various woods practices on the four basic resources was rated. Increases were shown in water yield, game forage, quality timber growth, and general use of the area. Some unresolved conflicts among uses of the forest were revealed. A 22-acre catchment was cleared of hardwood forest in 1958 and 1959 and seeded to Kentucky 31 fescue grass in 1959 and 1960. The amount of evapotranspiration by the grass cover was closely related to the amount of grass produced. During years when grass production was high, water yield from the catchment was about the same as or less than the expected yield from the original forest. As grass productivity declined, water yield gradually increased until it exceeded the predicted yield from the forest by over 5 inches annually. The grass appeared to evaporate more water early in the spring and less water late in the summer than the original forest cover.
- (h) "Conversion of Hardwood-Covered Watersheds to White Pine Reduces Water Yield," W. T. Swank and N. H. Miner, Water Resources Res., 4(5):947-954, 1968.
- "Blending Forest Uses," John D. Hewlett and James E. Douglass, Southeastern Forest Exp. Sta., USDA Forest Service Research Paper SE-37, 15 pp., 1968.
- "Low Herbicide Concentration Found in Streamflow After A Grass Cover Is Killed," J. E. Douglass and others, USDA Forest Service Research Note

SE-108, 3 pp., 1969.

"Water Yield Changes After Converting a Forested Catchment to Grass," A. R. Hibbert, Water Resources Res. 5(3), 634-640, 1969.

(5813)

HYDROLOGY AND MANAGEMENT OF WETLAND FORESTS.

(d) Experimental; applied and basic research.

(e) Project objective is to develop effective and reliable water control and soil management techniques through increased knowledge of the hydrology, soil properties, and soil-water-plant relations of wetland forests. Research is concentrated on three major problems: (1) define the natural hydrology of the major physiographic wetland types: bottomlands, bays and pocosins, and wet flatlands; (2) determine the effects of principal engineering water control measures on area hydrology and soil properties; and (3) determine the effects of vegetal manipulation on area hydrology and soil properties. Studies are conducted in wetland forests throughout the southeastern coastal plain from Virginia through Florida. Accordingly, much of the program consists of water control and soil research in cooperation with wood-using industries and other wetland forest managers who have made or plan to make capital investments to manage water on their land. In addition, research is conducted on the Santee Experimental Forest, located 32 miles north of Charleston, S. C., which has a small laboratory and four stream gaging stations on watersheds of 400, 550, 1200, and 11,000 acres.

(g) Preliminary results from a 400-acre wetland watershed show that average annual storm runoff was approximately twice that from forested watersheds in the Piedmont and Mountains. Furthermore, during wet periods, peak runoff rates were double those computed for the watershed by an accepted runoff formula. However, streamflow was intermittent with no flow periods as long as one to two months occurring each year. Measured evapotranspiration was slightly greater than Thornthwaite's potential ET. Large acreages of organic soils in the South are available for woodland production, but landowners need information on these soils to aid in their management. Criteria needed include botanical origin, depth, degree of decomposition, acidity, water sources, and water conductivity rates. Water management on wetland soils continues to accelerate in the Southeast. However, it has been found that trees planted on these sites can be severely damaged by wind if they are improperly planted. In another study on drained land, statistical models were developed to express the relationship between (1) depth of water table and soil moisture content at 6 to 18 inches, and (2) depth to water table and oxygen diffusion rate at 12 inches.

(h) "Opportunities for Water Management in Coastal Plain Woodlands," Ralph A. Klawitter, Southern Lumberman, Vol. 215 (2680): 175-177, 1967. "Streamflow - An Important Factor in Forest Management in the Coastal Plain," Cortland E. Young, Jr., Southern Lumberman, Vol. 215 (2680): 109-110, 1967.

"Hydrology of Wetland Forest Watersheds," Cortland E. Young, Jr., and Ralph A. Klawitter, Conf. Proc. Hydrology in Water Resources Management, Clemson Univ., WRRI Report No. 4, pp. 29-38, 1968.

"Soils Information Used and Needed for Woodland Production: Research Findings -- Organic Soils," Ralph A. Klawitter, Proc. Southern Regional Technical Work - Planning Conf., Cooperative Soil Survey, July 9-11, 1968, Clemson Univ., Clemson, S. C.

"Wind Damages Improperly Planted Slash Pine," Ralph A. Klawitter, Southern Lumberman, Vol. 218 (2709): 24, 1969.

"Water Table, Soil Moisture, and Oxygen Diffusion Relationships on Two Drained Wetland Forest Sites," Cortland E. Young, Jr., Soil Sci. 107: 200-222, 1969.

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U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, SOUTHERN FOREST EXPERIMENT STATION, T-10210 Federal Building, 701 Loyola Avenue, New Orleans, Louisiana 70113. R. L. Youngs, Director.

(6973)

IMPROVEMENT IN TIMING OF WATER YIELD ON FOREST WATERSHEDS IN THE OZARK-OUACHITA HIGHLANDS.

(d) Field investigations; applied research.

(e) Objective is to formulate watershed management practices for prolonging summer flow of streams in the Ozark-Ouachita Highlands. Research is concentrated on: (1) identifying hydrologic characteristics of soils showing greatest potential for receiving and storing water to augment streamflow during summer, (2) determining locations and extent of such soils, and (3) assessing responses of these sites to methods of vegetation manipulation designed to stabilize streamflow. Runoff and sediment are measured on three small watersheds in the Ouachita Mountains and on six in the Ozark Mountains. Ground water is monitored by neutron probe on watersheds in both mountain areas. Calibration has been achieved on the Ouachita watersheds, and changes in forest vegetation were imposed on two units during 1969. Calibration is continuing on Ozark watersheds, with two scheduled for treatment of overstory in 1970. Related studies of soil water receipt and disposal are conducted on plots.

(g) Results to date have been mainly in the development and improvement of techniques and equipment needed to measure water and sediments.

(6974)

DEVELOPMENT OF REHABILITATION AND MANAGEMENT TECHNIQUES FOR FOREST WATERSHEDS ON ERODED OR HIGHLY ERODIVE SITES IN THE SOUTHERN COASTAL PLAIN AND PIEDMONT REGIONS.

(b) Laboratory project, in cooperation with Soil Conservation Service and the University of Mississippi.

(d) Field investigations; basic and applied research.

(e) Objectives are: (1) to develop methods for establishing vegetation to retard runoff and erosion on depleted forest sites, and (2) to formulate methods for minimizing runoff and erosion on rehabilitated forest sites as a result of cultural treatments, harvesting, and regeneration. Information is acquired concerning factors that limit establishment, growth, and maintenance of protective cover on forest land. Limitations investigated include adaptability of native and exotic species to deteriorated sites, protective values of such plants, and means whereby eroded soils can be ameliorated to favor establishment and growth of cover. Rehabilitation studies are conducted on sites ranging from friable sands and loess deposits of the upper Coastal Plain to exposed clay subsoils representative of Piedmont sites. Investigations are conducted to assess effects on runoff and erosion of forest thinning intensities and schedules, harvest cuts, site preparation, regeneration techniques, prescribed burning, control of cull hardwoods, and logging methods.

- (g) Study has shown that loblolly pines retard runoff and eliminate accelerated erosion after canopies are closed, but from establishment to crown closure litter accumulation is insufficient for optimum protection. Fertilization of pines has increased needle production and thereby accelerated litter accumulation, but supplemental vegetation is needed to stabilize many sites, pending establishment of pine litter cover. Among numerous herbs evaluated, several introduced grasses have proven suitable for supplementing pine plantations. On very severe sites, organic mulches have materially reduced erosion during two years following pine establishment.
- (h) "Logging Disturbance on Erosive Sites in North Mississippi," B. P. Dickerson, USDA Forest Serv. Res. Note SO-72, 4 pp., 1968.
 "Fertilizing with Nitrogen and Phosphorus Increases Loblolly Pine Foliage Production," P. B. Duffy, J. Miss. Acad. Sci. 13: 21-23, 1967.
 "Growth of Pine Planted for Erosion Control in North Mississippi," H. L. Williston, USDA Forest Serv. Res. Note SO-69, 4 pp., 1967.
 "Improving Loblolly Pine Survival in Roadbank Stabilization," H. L. Williston, USDA Forest Serv. Tree Planters' Notes 18(3): 18-20, 1967.

(6975)

IMPROVEMENT OF GROUND-WATER SUPPLIES IN THE SOUTHERN COASTAL PLAIN.

- (d) Field investigations; applied research.
 (e) Objectives are: (1) to develop cover conditions and land-use methods on forest areas to regulate volume, quality, and distribution of surface water; and (2) to augment groundwater supplies in important recharge areas and on watersheds. Investigations are designed to facilitate: (a) identification of geologic conditions and outcrop areas where management of cover to augment aquifer recharge is most feasible; (b) development of techniques for assessment of water storage and transmission capacities of important outcrops; (c) evaluation of forest conditions affecting water entry into the soil and the quantity available for deep recharge; and, (d) development of forest management methods that favor increase of ground-water.
- (g) Study has demonstrated that pine plantations on eroded Coastal Plain sites are reducing sedimentation and at the same time effectively restoring the ability of permeable outcrops to accept and store rainfall. On grass-covered watershed with predominantly well-drained soils, prescribed burning increased stormflows, overland flows, peak discharges, and sediment production for at least three years. Identical treatment on a catchment having soil with a shallow fragipan increased overland flows, peak flows, and sediment yield but did not influence storm-flow volumes. A computer program has been developed for converting neutron probe readings to soil water equivalents, and source decks and detailed instructions have been made available.
- (h) "Reforestation and Water Resources of the Yazoo-Little Tallahatchie Watershed," S. J. Ursic, Miss. Water Resources Conf. Proc. 1968: 9-13.
 "Hydrologic Effects of Prescribed Burning on Abandoned Fields in Northern Mississippi," S. J. Ursic, USDA Forest Serv. Res. Paper SO-46, 20 pp., 1969.
 "Computer Program for Converting Neutron Probe Readings to Soil Water Equivalents," T. W. Popham and S. J. Ursic, Soil Sci. 107: 302, 1969.
 "New Neutron Probe System Speeds Logging of Soil Water Profiles," T. L. Rogerson and S. J. Ursic, In 14th Congr. Proc. Int. Union Forest. Res.

DEPARTMENT OF THE AIR FORCE, AIR FORCE INSTITUTE OF TECHNOLOGY, Aerospace Design Center, Wright-Patterson Air Force Base, Ohio 45433. Harold C. Larsen, Director.

(7090)

TRANSONIC AIRFOIL SIMULATION BY THE HYDRAULIC ANALOGY.

- (d) Master's thesis.
 (e) A water tow tank was used to simulate transonic flow about bodies and airfoils. Data was obtained by measuring grid line shift and distortion reflected off the surface of the water. Mass ejection from the trailing edge was used to stabilize and control trailing edge shock.
 (f) Suspended.
 (g) Qualitative and quantitative results agree with wind tunnel data obtained on a similar model. More development work is needed to improve accuracy, but method lends itself to a rapid inexpensive method of exploring new shapes prior to wind tunnel testing.
 (h) "Transonic Airfoil Simulation by the Hydraulic Analogy," James A. Ball, Thesis, GAM/AE/70-1.

DEPARTMENT OF THE AIR FORCE, AEROSPACE RESEARCH LABORATORIES, APPLIED MATHEMATICS RESEARCH LABORATORY, Wright-Patterson Air Force Base, Ohio 45433. Dr. Lynn E. Wolaver, Director.

(6976)

KAPITZA'S METHOD FOR FILM FLOW DESCRIPTION.

- (c) Dr. Jon Lee.
 (d) Theoretical applied research.
 (e) The aim of this project is to improve the classical Kapitza's method for predicting the wave amplitude and wave speed of pseudolaminar film flows over an inclined flat plate, under gravity. In Kapitza's original treatment, the equilibrium wave amplitude was estimated by invoking a plausible argument which involves minimizing energy dissipation by viscosity. Here we have first rederived Kapitza's third-order equation for the surface wave motion associated with pseudolaminar flow by consistently applying the boundary layer approximation to the Navier-Stokes equations and free surface conditions, and then have deduced the equilibrium wave amplitude using the nonlinear oscillation theory.
 (f) Completed.
 (g) The main contribution of our work is the derivation of the wave amplitude from the dynamic equations by investigating the nonlinear effect on an isolated class of periodic wave motions pertaining to the linear system. Our predicted wave amplitude and wave speed obtained as the first-order approximation are in good agreement over the entire Weber number range with the experimental data of Kapitza & Kapitza (Zh. eksp. teor. Fiz. 105, 19, 1949) and Jones & Whitaker (A.E.Ch.E. J1., 525, 12, 1966).
 (h) "Kapitza's Method for Film Flow Description," J. Lee, Chem. Engr. Sci., 1309, 24 (1969).

DEPARTMENT OF THE AIR FORCE, ARNOLD ENGINEERING DEVELOPMENT CENTER, Arnold Air Force Station, Tennessee 37389. Brig. Gen. Jessup D. Lowe, Commander.

(7449)

LAMINAR BOUNDARY LAYER FLOWS OF NON-NEWTONIAN FLUIDS.

- (c) Elton R. Thompson, Advanced Plans Division (AELA), Directorate of Plans and Technology, Arnold Engrg. Dev. Ctr., Tullahoma, Tenn.
- (d) Theoretical; Ph.D. thesis.
- (e) A study of the viscous flow field associated with laminar, external flows of power-law, non-Newtonian fluids. Both mass and heat transfer effects are included in the investigation.
- (g) A method of solving the energy equation via application of similarity solution concepts has been obtained. Influence of surface mass injection on viscous and thermal boundary layer properties has been determined.
- (h) "Similar Solutions of the Boundary Layer Equations for a Non-Newtonian Fluid," E. R. Thompson, J. Hydronautics, Vol. 3, July 1969.
- "Similarity Solutions: Application to Incompressible Boundaries with Non-Newtonian Injectants," E. R. Thompson, J. of Franklin Institute, Special Issue, Dec. 1969.
- "Laminar Boundary Layer Flows of Newtonian Fluids with Non-Newtonian Fluid Injectants," J. Hydronautics, Vol. 2, April 1970.

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DEPARTMENT OF THE ARMY, U. S. ARMY COLD REGIONS RESEARCH AND ENGINEERING LABORATORY, P. O. Box 282, Hanover, New Hampshire 03755. Director.

(052W)

THERMAL CALCULATION TECHNIQUES.

- (c) Richard Berg, Research Civil Engineer.
- (e) Study of heat transfer and heat flow computations in soils and construction material subject to freezing and thawing.
- (f) Completed.
- For summary, see Water Resources Research Catalog, Vol. 3, 2.0718.

(053W)

CULVERTS, DRAINS AND CONDUITS IN PERMAFROST.

- (c) R. Huck, Research Civil Engineer.
- For summary, see Water Resources Research Catalog.

(054W)

UTILITIES IN PERMAFROST AREAS.

- (c) S. C. Reed, Research Civil Engineer.
- For summary, see Water Resources Research Catalog, Vol. 4, 2.0756.

(055W)

TECHNICAL SUPPORT, INVESTIGATIONS OF ARTIC CONSTRUCTION.

- (c) C. W. Fulwider, Research Civil Engineer.
- For summary, see Water Resources Research Catalog, Vol. 3, 8.0276.

(6383)

HYDROLOGY OF A SMALL DRAINAGE BASIN ON THE COASTAL PLAIN OF NORTHERN ALASKA.

- (c) Dr. Jerry Brown, Research Soil Scientist.
- (d) Field and experimental.
- (e) Provides hydrogeological data in support of soils and vegetation processes at Barrow, Alaska, and obtains information on the water balance in a coastal tundra environment underlain by permafrost.
- (f) Completed.

- (g) Runoff varies widely; hydrograph analyses revealed: (1) lag times generally from 3 to 10 hrs.; (2) recession constants about 50 hrs.; (3) runoff from individual storms between 1 and 70%. Assuming all winter precipitation runs off over the seasonally frozen ground and the data are spatially and temporarily representative, about 50% of the measured annual precipitation in this region runs off into the Arctic Ocean.
- (h) USACRREL Research Report No. RR 240, "Hydrology of a Drainage Basin on the Alaskan Coastal Plain," J. Brown, S. L. Dingman, R. I. Jewellen (available from CFSTI, AD671005; also Amer. Geophys. Union, Trans. Vol. 48, p. 93).

(6384)

RECONNAISSANCE HYDROLOGIC STUDY OF THE DELTA RIVER AND ITS DRAINAGE BASIN, EAST-CENTRAL ALASKA.

- (c) S. Lawrence Dingman, Research Hydrologist.
- (d) Field study; basic.
- (e) A one-year reconnaissance study of a large braided glacial river and its drainage basin (drainage area - 1665 mi^2 ; elevation range 1000 - 10,000 ft.) for which a minimum of hydrometric and meteorologic data existed. Includes estimates of the water-balance, flow-duration curves, and sediment characteristics, and descriptions of stream response to glacial melt and rain, channel geometry and channel processes.
- (f) Completed.
- (g) Mean annual basin precipitation is estimated at 40.4 in. and a mean annual loss of permanent glacial storage is about 1 in. About 30% of this leaves the basin as evapotranspiration, 50% as streamflow, and 20% as groundwater flow. Characteristics of response to glacial melt are outlined. Flow peaks near the mouth occur within 24 hours of rainfall of greater than 0.5 in./day at foothills meteorological stations; rains of less than that amount do not generally produce discernible stream response. Stream channel geometry is described in detail - most channels on the lower flood plain are asymmetrical and are roughly triangular or parabolic, and have high width/depth ratios. At-a-station hydraulic geometry is described. Surveys and ground and aerial photography are used to describe channel changes.
- (h) USA CRREL Research Report "The Delta River and Its Drainage Basin - Reconnaissance Hydrological Study," S. Lawrence Dingman, et al. (in press), available from USA CRREL, Box 282, Hanover, N. H. 03755.

(6385)

HYDROLOGIC STUDY OF THE GLENN CREEK DRAINAGE BASIN NEAR FAIRBANKS, ALASKA.

- (c) S. Lawrence Dingman, Research Hydrologist.
- (d) Field study; basic doctoral thesis.
- (e) A study of runoff characteristics and thermal erosion in a sub-arctic watershed of 0.7 mi^2 area, largely underlain by permafrost. Measurements of rainfall, runoff, pan evaporation, moss evaporation, solar radiation, wind, air and water temperature, and relative humidity have been made over parts of four summers.
- (f) Completed.
- (g) Rainfall-runoff measurements have shown very slow recessions and long lag-times relative to similar-sized and even much larger watersheds in more temperate regions. The thick moss ground cover over much of the basin is thought to be responsible for their characteristics. Thermokarst features along the stream contribute a large burden of suspended sediment to the stream.
- (h) USA CRREL Special Rept. 86 "Hydrologic Studies of the Glenn Creek Drainage Basin Near Fairbanks, Alaska," S. Lawrence Dingman, 30 p., 1966.

Available from CFSTI, AD631948.

"Characteristics of Summer Runoff from a Small Watershed in Central Alaska," S. Lawrence Dingman, Water Resources Res., Vol. 2, No. 4, p. 751-754, 1966. (Available from author, USA CRREL.)

(6386)

CHARACTERISTICS OF ALASKAN STREAMS AND BASINS AS RELATED TO MILITARY MOBILITY.

- (b) U. S. Army Tank-Automotive Command.
- (c) Dr. Jerry Brown, Research Soil Scientist.
- (d) Field and experimental; basic and applied.
- (e) Objective is to evaluate interrelated hydrologic and morphologic characteristics of selected rivers and drainage basins in Alaska, for identifying, understanding and predicting characteristics of arctic and subarctic waterways as related to vehicular mobility problems. Basic hydrologic and morphologic data are collected in the Tanana River Basin, Alaska.
- (f) Completed.
- (g) The results of this study have shown that it is possible to predict the general channel type and magnitude (and thus the potential crossing problem) encountered in the subarctic area from knowledge of physiographic and geologic setting, basin size and watershed characteristics.
- (h) A final report "Alaskan Stream and Basin Characteristics Pertinent to Military Mobility," July 1968, has been submitted to the sponsor. Additionally, a paper has been prepared for publication in 1970 in J. of Terramechanics entitled "Prediction of Stream Frequency."

(6387)

THE EFFECTS OF THERMAL POLLUTION ON RIVER ICE CONDITIONS.

- (c) W. F. Weeks, Research Geologist.
- (d) Field and theoretical.
- (e) Measure temperature changes in the North Platte River, Wyo., below a large steam power plant. Relate heat dissipation to meteorological conditions to verify a theoretical model.
- (f) Theoretical modeling completed and described in 1968 summary. Field results presently being examined.
- (g) Results await reduction of 1969 data.
- (h) USA CRREL Research Rept. 206 "The Effects of Thermal Pollution on River Ice Conditions," S. L. Dingman, W. F. Weeks, and Y. C. Yen (available from CFSTI, AD 66205: Part I and AD 694372: Part II).
"The Effects of Thermal Pollution on River Ice Conditions," S. L. Dingman, W. F. Weeks, and Y. C. Yen, Water Resources Res., 1968. (Available from authors, USA CRREL.)
USA CRREL Research Rept. "Heat Transfer Coefficients for Calculation of Downstream Cooling of a River Below a Thermal Pollution Source," A. Assur and S. L. Dingman (in preparation).
Available from USA CRREL.

(6388)

APPLIED MECHANICS OF FLOATING ICE.

- (b) Corps of Engineers.
- (c) G. Frankenstein, Research Civil Engineer.
- (d) Applied research; field investigations.
- (e) Several rivers are being investigated for frequency of ice jam formation. Measurements are being made of ice thickness, snow depth and water depth at main channel.
- (h) Results of the studies conducted on the White River, Hartford, Vermont, area are reported in a Technical Note (internal report) by Garner and Frankenstein.

(6987)

HYDROLOGY OF PERMAFROST AND NONPERMAFROST TERRAIN IN INTERIOR ALASKA.

- (c) Dr. Charles Slaughter, USACRREL, Box 1601, Fairbanks, Alaska.
- (d) Field and experimental.
- (e) Investigate runoff and climatologic characteristics in small adjacent watersheds to determine the influence of permafrost on hydrologic regime of Taiga Terrain. Calibrate small watersheds prior to terrain manipulation to determine influence of natural and man-made disturbances on runoff characteristics over permafrost.
- (g) Initial results not presently available.

(6988)

TOPOLOGIC AND HYDROLOGIC CHARACTERISTICS OF GEOLOGICALLY CONTROLLED STREAM NETWORKS.

- (c) Mr. Steven J. Mock, Research Geologist.
- (d) Field, theoretical, Ph.D. thesis.
- (e) To examine topologic properties of geologically controlled (trellis) stream networks from basis of recent theoretical models; to study the distributions of stream links by type and length within stream networks; to examine the interrelationships between topologic, link, and hydrologic properties.

(6989)

ANALYSIS OF LAKE TEMPERATURE OBSERVATIONS BY USE OF SPLINE FUNCTIONS.

- (c) Dr. Shunsuke Takagi, Research Physical Scientist.
- (d) Field and theoretical.
- (e) The quantity $\int (\partial\theta/\partial t - \kappa \partial^2\theta/\partial x^2) dx$, where θ is temperature as function of x and t , and the range of integrations is over the range of x , must be minimum, when only the one-dimensional heat conduction is the mechanism of heat transfer, and becomes larger when some other heat transfer mechanisms take place together with the one-dimensional heat conduction. This principle can be carried into actual computation by use of spline functions. Lake temperature observations are analyzed as an application.
- (f) Completed.
- (g) Use of spline functions to analyze the temperature observed in a lake identified the period during which only vertical heat conduction was the mechanism of heat transfer. If the scattering due to observation errors is disregarded, a quantity called "the integral residual" becomes a minimum in this period. The standard deviation of the temperature observation can be found from the scattering. Only the differential equation and none of the boundary and initial conditions are needed in this computation.
- (h) "Spline Function Applied to Analyzing Lake Temperature Observations," in process of publication.

(6990)

EVAPORATION OF WATER INTO A COLD AIR STREAM.

- (b) Defense Intelligence Agency.
- (c) Dr. Yin-Chao Yen, Research Physical Scientist.
- (d) Experimental and theoretical; basic and applied.
- (e) To determine the heat transfer processes from a relatively warm body of water to a cold air stream. This simulates a condition similar to the environmental situation prevailing in rivers and lakes of North America under winter conditions. It is expected that for air much cooler than the water, condensation may occur as the water vapor leaves the water surface. Therefore, it is suspected that under this condition, the conventional expression used to show the analogy between heat and mass transfer from a plane fluid surface can be used to evaluate the rates of heat

- and mass transfer.
- (f) Refinement of the experimental techniques is underway.
- (h) "Evaporation of Water Into a Sub-Zero Air Stream," Y.-C. Yen and G. R. Landvatter, Water Resources Res., Vol. 6, No. 2, pp. 430-439, 1970.

(6991)

THE TEMPERATURE STRUCTURE OF A MID-LATITUDE DIMICTIC LAKE DURING FREEZING, ICE COVER, AND THAWING.

- (c) Mr. W. H. Parrott, Research Physicist.
- (d) Field project.
- (e) A small mid-latitude lake was instrumented primarily for temperature at 24 points at a vertical section at the deepest point in the lake. These data were taken every hour at all points. These data were analyzed during the periods of freeze-up, ice cover, and thaw. The heat balance of the lake was determined for different thermal structures of the lake and different meteorological conditions. The temperature of the bottom muds was measured to determine the contribution of energy stored in the bottom.
- (g) Complete results have not been determined as the project is still actively collecting data. To date the lake has behaved classically with a complete turnover occurring in the fall and becoming isothermal at approximately 4°C and then continued cooling to ice cover. A more rapid turn occurs in the spring producing a stratified lake with a well defined thermocline.
- (h) USACRREL Research Report "The Temperature Structure of a Mid-Latitude Dimictic Lake During Freezing, Ice Cover, and Thawing," W. H. Parrott and W. M. Fleming (in preparation, 1970).

(6992)

ESTIMATING STREAMFLOW CHARACTERISTICS USING AIRPHOTOS.

- (c) Robert E. Frost, Civil Engineer (E. A. Joering, Civil Engineer, performed work and is now at Civil Engineering Department, University of Cincinnati).
- (d) Experimental and field investigation, applied research.
- (e) Part of continuing development and application of photographic interpretation techniques to evaluation of hydrologic properties of terrain. Part one of the study is concerned with studies of three watershed sites in Alaska where features considered were channel, roughness, discharge, velocity and depth. Part two of the study involved looking at five stream reaches in a controlled watershed in northern Vermont.
- (f) Inactive.
- (g) The encouraging results suggest that airphoto analysis can provide an excellent means of obtaining at least reconnaissance-type surface water data. The method used affords the planner of water supply, flood control or military mobility a first order source of information which is sufficiently reliable for rapid preliminary planning and at low cost.
- (h) USACRREL Tech. Note, "Estimating Streamflow Characteristics Using Airphotos," Sept. 1969 (available from USACRREL).

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DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS, COASTAL ENGINEERING RESEARCH CENTER, 5201 Little Falls Road, N. W., Washington, D. C. 20016. Lt. Col. Edward M. Willis, CE, Director.

(181)

EQUILIBRIUM PROFILE OF BEACHES AND STUDY OF MODEL SCALE EFFECTS.

- (d) Experimental; basic research.
- (e) Equilibrium beach profiles will be determined experimentally for waves up to 6 feet in height in a prototype tank; the waves will be modeled at a 1 to 10 scale in small laboratory tanks (to determine scale effects) for various median diameter and specific gravity sediments.
- (g) Study continues in an attempt to define scale characteristics for beach sediment under wave action, using, as a sand simulant, glass beads with a mean diameter of about 115 microns. A study was made to compare model beach profiles obtained with the sand simulant with those obtained using quartz sand with a mean diameter of about 200 microns and waves up to 5.5 feet in height in the 635-foot wave tank. A 1 on 10 scale model beach was built in one of the small wave tanks at CERC. Different wave conditions were run, and periodic beach profiles made to determine the response of the beach to wave attack. Time lapse movies were taken to show the development of various beach features. Analysis is yet to be completed, but the "sand simulant" profiles did not compare well.
- (h) "Bed Forms Generated in the Laboratory Under an Oscillatory Flow: Analytical and Experimental Study," M. R. Carstens, F. M. Neilson, and H. D. Altinbilek, U. S. Army Coastal Engrg. Res. Ctr. Tech. Memo. No. 28, June 1969.
- "Oolitic Aragonite and Quartz Sand; Laboratory Comparison Under Wave Action," Frederick F. Monroe, CERC Miscellaneous Paper No. 1-69, 84 pp., April 1969.

(660)

OBSERVED WAVE CHARACTERISTICS.

- (d) Field investigation; basic research.
- (e) To secure a more thorough knowledge of the characteristics of ocean waves. Wave gages have been installed in a number of locations in coastal waters. These wave gages provide a pen and ink strip chart recording and also magnetic tape recordings. The records from the paper chart records are analyzed for significant wave height and wave period. The records from the magnetic tape recorders are analyzed to provide a spectral analysis of wave frequency (or period) versus: (1) linear average wave height; (2) squared average wave height; and (3) peak wave height.
- (g) The program for collecting wave data using recording type wave sensors was expanded during FY's 67, 68, and 69. All East Coast wave recording stations were adapted to telemeter the wave data from each station to the CERC laboratory on a full-time basis by leased telephone lines. Data from each station is recorded on pen-and-ink strip chart recorders and on digital magnetic tape. Wave gage development during this period included microwave, infrared, and laser type sensors. The laser type wave sensor shows some promise for wave height measurement. Several schemes for obtaining wave direction measurement were considered during this period. These devices included a flowmeter, Rayleigh disc, Banwell force gage, and several surface gages used in a spaced array. Further research on wave direction measurement techniques is in progress.
- A test for determining the pressure-depth wave

- height correlation was begun at Atlantic City, N. J. This study uses three wave gages mounted in a vertical column. The waves recorded by two pressure sensors at different depths are being compared to surface waves measured with a Baylor wave staff. This test will continue when fire damage to Steel Pier in Atlantic City has been restored.
- (h) "CERC Wave Gages," Leo C. Williams, Coastal Engrg. Res. Ctr. Tech. Memo. No. 30, 123 pp., Dec. 1969. "The Wave Record Program at CERC," J. M. Darling and D. G. Dumm, CERC Misc. Paper No. 1-67, 30 pp., January 1967.
- (1975)
METHODS OF BY-PASSING SAND PAST INLETS.
- (c) G. M. Watts, Chief, Engrg. Development Division.
(d) Field investigation; applied research.
(e) To study methods and requirements for pumping sand past inlets and to determine the applicability of the methods in stabilization of beaches adjacent to inlets. Data procured at selected locations include periodic hydrographic surveys south and north of the inlet, wave data, sand samples, detailed records of pumping operations, and detailed records of entrance channel maintenance.
(g) Surveys, observation and data compilation are in progress at a submerged weir and deposition basin sand by-passing operation at Masonboro Inlet, N.C.
(h) "Coastal Regime," Thorndike Saville, Jr., and George M. Watts, XXII Intl. Congr. Perm. Intl. Assoc. Navigation Congresses, 20 pp., June 1969.
- (2190)
STUDY OF EFFECT OF A GROIN ON THE RATE OF LITTORAL MOVEMENT.
- (c) Thorndike Saville, Jr., Chief, Research Division.
(d) Experimental; basic research.
(e) To study the effect of groins on the rate of littoral drift passing a groin system. Initial tests consist of waves generated at a 30-degree angle to the sand beach with measurement of material movement being made at the downdrift end. The tests planned for the immediate future, as have the current season tests, will continue to emphasize the task of collecting and establishing reliable calibration data on the relationship between the littoral transport rate and the wave characteristics. These generalized (not to specific model scale) studies are being made in the Shore Processes Test Basin of the Coastal Engineering Research Center.
(g) Laboratory testing in the Shore Processes Test Basin for the determination of the relationship between incident wave characteristics and the rate of alongshore transport was temporarily discontinued in October 1966. The main reason for discontinuance of the tests was the considerable difficulty experienced with wave-height variation with both time and location. The most recent laboratory summary report of these tests was prepared for the period 1964-1966 and is available on loan from the CERC Library. Similar laboratory summaries of these tests made previous to 1964 are available at CERC on a limited distribution basis. A report of these tests is in preparation and is expected to be published in late 1970.
- (2193)
SHORE PROTECTION PLANNING AND DESIGN.
- (c) R. A. Jachowski, Chief, Design Branch.
(d) Design.
(e) To supplement and revise the Coastal Engrg. Res. Center's (formerly Beach Erosion Board) Technical Kept. No. 4, "Shore Protection Planning and Design," as new data and techniques are developed for use in the solution of coastal engineering problems.
- (g) The third edition of this comprehensive manual is published and available from Supt. of Documents, U.S.G.P.O., Washington, D. C. 20025, for \$3.00 per copy. A cross referenced index for this manual has been prepared for inclusion in possible reprint of present 3d edition. The outline for complete new format for 4th edition of this manual has been tentatively formulated.
- (2195)
COASTAL WORKS EVALUATION.
- (c) G. M. Watts, Chief, Engineering Development Div.
(d) Field investigation; applied research.
(e) Data are collected before, during, and after construction of shore structures including repetitive surveys, material sampling, littoral forces (to extent possible) and that relating to techniques and materials of construction. The data are machine processed, collated and studied. The purpose is to procure and develop data on all types of shore improvement structures and methods, to be used to determine their effectiveness and to develop new criteria or changes in existing criteria applicable to functional and structural design of future structures.
(g) Follow-up studies continue at Hunting Island, S. C., Presque Isle, Pa., Wrightsville Beach & Masonboro Inlet, N. C., Carolina Beach, N. C., Wallis Sands Beach, N. H., and the revetments at Fort Story and the Chesapeake Bay Bridge-Tunnel terminal islands in Virginia; to continue basic data collection and project surveillance in cooperative studies with State of California; to continue basic data collection and structure surveillance in Hawaii; and monitor beach changes on the Gulf Coast of Texas. Also provided were post-storm (CAMILLE) surveys, bottom samples, and aerial photography of beach erosion control project area of Harrison County, Miss., to study in cooperation with the State of Florida experimental dredging of ocean bottom for beach fill with an experimental submarine dredge; to monitor and film placement of concrete-filled Jutlon bags to strengthen north jetty at Grays Harbor, Wash.; and film and monitor local construction of an experimental type groin at Ocean Beach, LI, N. Y.
- (h) "Effect of Particle Size and Distribution on Stability of Artificially Filled Beach, Presque Isle Peninsula, Pennsylvania," Dennis W. Berg and David B. Duane, Coastal Engrg. Res. Ctr. Reprint R 1-69, April 1968.
"Prototype Investigation of Stability of Quadrupod Cover Layer, Santa Cruz Harbor, California," O. F. Weymouth and O. T. Magoon, Coastal Engrg. Res. Ctr. Reprint 2-69, Sept. 1968.
"Systematic Collection of Beach Data," by Dennis W. Berg, Coastal Engrg. Res. Ctr. Reprint R 4-69, Sept. 1968.
- (2660)
MEASUREMENT OF SUSPENDED MATERIAL UNDER WAVE ACTION.
- (c) R. P. Savage, Chief, General Projects Branch.
(d) Experimental; basic research.
(e) To determine the relationship between wave, water, and sand characteristics, and the amount of material maintained in suspension and, hence, available for longshore transport by currents.
(g) Analysis of suspended sand samples collected at Nags Head, N. C. (1964) and Ventnor, N. J. (1965) have been completed and reports of the field sampling and analysis are under review. Study of the glass beads sand simulant also included collection (by pumping) of suspended sediment samples

(see Item 181). Preliminary analysis shows that for a prototype wave of 11.33-second period and 5 to 5.5-foot height, suspended sediment concentrations for both prototype (large wave tank tests) and the model tests (glass beads sand simulant) lie within the range of 1 to 40 parts per thousand by weight.

(4661)

WAVE RUN-UP ON SHORE STRUCTURES.

(c) R. P. Savage, Chief, General Projects Branch.
(d) Experimental; design.

(e) Wave run-up is determined experimentally for various waves for different types of shore structures. Effect of both structure roughness and permeability is being investigated.

(g) Tests are planned for a 72-foot wave tank involving the collection of wave run-up data on various slopes using both monochromatic waves and selected wave spectra. It is also planned to measure the pressure head due to run-up at several points on the slope. The tests will proceed as components for instrumentation are acquired and assembled. The draft report on the field measurements of wave run-up made on a North Carolina beach was reviewed and it was decided that it should not be published at the present time. However, the data will be included in a report on wave tank work now being planned. The wave tank work, described above, will include tests with various wave spectra starting with simple spectra and moving to more complicated spectra.

(3228)

MODEL TESTS OF WAVE SET-UP ON BEACHES.

(c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.

(d) Experimental; basic research.

(e) Measurement of the mean water level of shoaling waves on beaches using damped piezometers buried in the beach. Study is being made in order to (1) check existing theory for setup offshore of breaking; (2) estimate rate of energy supply required to maintain setup in surf zone; and (3) provide engineering criteria for design of coastal structures.

(g) In this study, analysis of the data from 92 tests is continuing. The ratio of maximum setdown to breaker height averaged 0.02, 0.03, and 0.07 for slopes of 0.05, 0.10, and 0.20, respectively. At the original stillwater line, the ratio of setup to breaker height averages about 0.21 with no obvious dependence on beach slope or breaker height. Offshore of the breaker point setdown is in approximate agreement with linear theory. Experimental results described briefly above were presented as a talk at the 1967 annual meeting of the American Geophysical Union.

(3897)

RADIOACTIVE TRACERS FOR BEACH STUDIES.

(c) D. B. Duane, Chief, Geology Branch.

(d) Experimental; research.

(e) Basic objective of the Radioisotopic Sand Tracer (RIST) Study at Point Conception, California, is to develop data and knowledge concerning littoral material transport in the vicinity of headlands or supposed barriers to littoral drift utilizing radioactive sand particles. The study will provide data, information, and guidance on development of techniques and necessary hardware for use in studying the characteristics of littoral material movement around headlands and will develop additional information on many other aspects of sediment transport.

(g) Field testing of radioactive tracers (gold-tagged

sand), and injection and detection apparatus were carried out at Surf, California, and at the site of the CERC prototype experimental groin (PEG) at Pt. Mugu, California. Analysis of data from these and previous tests was continued and a draft report on the computer program RAPLOT II used at CERC was completed and submitted for publication. Preparations to conduct field programs at Ocean-side, California, and preliminary discussion preparatory to holding tests at a location on the Atlantic Coast (Masonboro Inlet, N. C.) are underway.

(h) "Radioisotopic Sand Tracer Study, Point Conception, California: Preliminary Report on Accomplishments," David B. Duane and Charles W. Judge, Coastal Engrg. Res. Ctr. Misc. Paper No. 2-69, 194 pp., May 1969.

(4760)

EXPERIMENTAL STUDY OF DUNE BUILDING WITH SAND FENCES AND VEGETATION.

(c) R. P. Savage, Chief, General Projects Branch.

(d) Experimental; design.

(e) The experimental study consists of the construction of various types and arrangements of sand fences to determine the fence type and arrangement most effective in building a dune by trapping and holding wind-blown sand. Slat-type snow fencing and locally constructed brush fencing have been used in straight, straight-with-side spurs, and zigzag configurations. The study is being conducted on the Outer Banks of North Carolina between Cape Hatteras and Cape Lookout.

(g) In the North Carolina dune study area, periodic surveys were continued throughout the year. No new fencing was installed and no new grasses were planted but the old grass sections were maintained and followed. North Carolina State University continued to follow the experimental sections which have already been installed on Ocracoke Island.

A program for experimental installation of grass and fence sections in the Cape Cod area was developed and undertaken in cooperation with the New England Division of the Corps of Engineers. The experimental fence and grass sections were installed on a spit on the north side of Nauset Harbor entrance.

A two-part contract study of barrier dune creation and stabilization along the Texas coast was initiated in 1969. During the first year of study a contractor, the Gulf Universities Research Corporation, has surveyed the natural vegetation of the area and, using selected species, established a nursery there. Monthly plantings of selected species were made to determine the effect of time-of-year on the planting. Thus far, Sea Oats is the most promising vegetation and one of the Sea Oats sections has trapped about two cubic yards of sand per lineal foot of beach in the first year after it was planted. Sixteen fence sections have been installed on south Padre Island, each 400 feet long, consisting of two porositys of slat-type snow fencing and two fabric types. These sections were surveyed in June and December 1969 and are now filled with sand.

(h) "Creation and Stabilization of Coastal Barrier Dunes," R. P. Savage and W. W. Woodhouse, Jr., Coastal Engrg. Res. Ctr. Reprint R 4-69, Sept. 1968.

(4762)

BEACH EVALUATION PROGRAM.

(c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.

(d) Field and office investigation to develop quantitative correlation between storm violence and

- shore erosion.
- (e) Repetitive profiles are taken at selected beach areas. The storm wave action between surveys is analyzed and correlations between the wave action and observed profile changes are established. Repetitive profile lines were established in September 1962 at nine locations between Delaware Bay and Cape Cod. These profiles were resurveyed at weekly and bi-weekly intervals. The resurvey interval now is 4 to 6 weeks. Storm wave action is measured by the Coastal Engineering Research Center ocean wave gages and storm surges by U. S. Coast and Geodetic Survey tide gages.
- (g) In a program of beach evaluation, repetitive profiles are taken at selected beach areas. Any storm-wave action between surveys is analyzed, and correlations between the wave action and observed profile changes are established as a beach-vulnerability criteria. In September 1962, repetitive profile lines were established at nine locations between Delaware Bay and Cape Cod. Profiles at these locations were originally resurveyed at weekly and biweekly intervals. Current resurvey interval is about 6 weeks. Storm waves are measured by CERC ocean wave gages and storm surges by USCGS tide gages at locations as nearby as possible.
- In 1968, repeat surveys were made at eight beaches from southern New Jersey to Rhode Island in the manner and on the profiles previously established. A laboratory report (see (h) below) was prepared to include general information on the study. On each of five beaches (two on Long Island, three in southern New Jersey), rows of pipe were placed along two selected profiles, and the sand levels at the pipes were observed weekly. These pipe profiles may be an economical substitute for conventional surveys on some beaches.
- Automation of the data continues with the digitizing, plotting, and computing of profile changes being completed for the entire backlog of surveys. Scanning forms for data acquisition are now in use. Data from Pipe Profile and Wave Observation Forms have been digitized, and initial analysis has begun. Maximum values of sand-level change for 1-week intervals at the pipe profiles on the eight original beaches during the third quarter of FY 1969 were similar to the values obtained for the same period in FY 1968. However, net 3-month changes showed significantly more erosion in FY 1969 than in FY 1968.
- (h) "Pipe Profile Data and Wave Observations from the CERC Beach Evaluation Program January-March 1968," H. D. Urban and C. J. Galvin, Jr., Coastal Engrg. Res. Ctr. MP 3-69, 74 pp., Sept. 1969.
- (4763)
SAND INVENTORY PROGRAM.
- (c) D. B. Duane, Chief, Geology Branch.
- (d) Field investigation; applied research.
- (e) For the purpose of delimiting and inventorying sand deposits in Atlantic, Pacific, Gulf or Great Lakes sub-bottom which would be potentially suitable and economic for beach fill at U. S. beaches, field surveys are carried out by contract at selected sites which include geophysical profiles by sonic device to determine stratification and cores to establish material characteristics.
- (g) Field work on sand inventory surveys to locate offshore sand deposits usable in shore restoration and maintenance projects were completed in the following areas:
All of New England south of Portland, Maine, and including the north and south shores of Long Island, N. Y.; Chesapeake Bay entrance and the Virginia coast from Cape Henry to Sand Bridge.
- Drafts of sand inventory reports have been completed, or are in preparation for the east coast of Florida, New Jersey, and Chesapeake Bay entrance.
- Procedures were worked out for transfer of Sand Inventory materials (cores and geophysical records) after use by CERC, to federal repositories where they will be made available to researchers for further study.
- (h) "Sand Inventory Program in Florida," D. B. Duane, Shore and Beach, Vol. 36, No. 1, pp. 12-15, 1968.
- "Sand Deposits on the Continental Shelf, A Presently Exploitable Resource," D. B. Duane, Trans. Natl. Symp. on Ocean Sciences and Engrg. of the Atlantic Shelf, Marine Technology Soc., Phila. Section, pp. 289-297, 1968.
- "Sand and Gravel Deposits in the Nearshore Continental Shelf, Sandy Hook to Cape May, New Jersey," D. B. Duane, Abstract with Program for 1969, Part 7, Geol. Soc. Am., pp. 53-54, 1969.
- "Sand Inventory Program, A Study of New Jersey and Northern New England Coastal Waters," D. B. Duane, Shore and Beach, Vol. 37, No. 2, pp. 12-16, 1969.
- "Shallow Structural Characteristics of Florida Atlantic Shelf as Revealed by Seismic Reflection Profiles," E. P. Meisburger and D. B. Duane, Trans. Gulf Coast Assoc. Geolog. Societies, Vol. XIX, pp. 207-215, 1969.
- "Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Florida," D. B. Duane and E. P. Meisburger, U. S. Army Coastal Engrg. Res. Ctr. Tech. Memo. No. 29, 1969.
- (5326)
RESONANT EDGE WAVES ON LABORATORY BEACHES.
- (c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.
- (d) Experimental.
- (e) An unusual standing wave in the runup on laboratory beaches is under study. The combinations of slope, period, breaker type, standing wave length, and resonant amplification are being measured in order to describe the phenomenon and to understand its effect on laboratory and natural beaches.
- (g) A report has been prepared for publication.
- (5328)
WAVE BREAKER STUDY.
- (c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.
- (d) Experimental and theoretical, basic research.
- (e) The wave height, mean water depth, and distance traveled in the breaking process are being measured for waves which break by plunging on a plane concrete beach in a wave tank 96 feet long and 1.5 feet wide. Parallel wire resistance wave gages measure the wave heights, damped piezometers buried flush with the beach surface measure the mean water level and photographs record the distance traveled in breaking. This study is undertaken to increase knowledge of the breaking process, to relate the energy flux of the incoming waves to the resulting wave setup, and to provide engineering criteria for the design of coastal structures.
- (g) Breaker types for waves on plane laboratory beaches were shown to be reasonably predicted by either of two dimensionless parameters. For waves on smooth concrete slopes, breaker type depends on beach slope, m , wave period, T , and either deep-water or breaker height, H_0 or H_b . For 43 varied laboratory conditions, breaker type was sorted fairly well by either of two dimensionless combinations of these variables; an offshore parameter, H_0/L_{0m}^2 , or an inshore parameter, H_b/gmT^2 . As either of these parameters increases,

breaker type changes from surging or collapsing to plunging or spilling.

In another study, an approximate calculation suggests that the minimum horizontal distance traveled by the crest of a plunging wave from the breaker position to its touchdown point is about 2 times the breaker height. Laboratory experiments on three plane beaches and on one composite beach indicate that the average value of this distance ranges from about 2 to more than 4 times the breaker height on plane beaches as slope decreases from 1 to 5 to 1 on 20. The tests have shown that structures sited in shallow water on moderate or steep slopes can be subject to breaking waves with heights significantly larger than would be predicted by accepted design practice. Computer programs have been developed which predict the breaking position and height at breaking of waves moving into shallow water.

- (h) "Horizontal Distance Traveled by a Plunging Wave," C. J. Galvin, Jr., ASCE Preprint 630, San Diego Mtg., 24 pp. 19-23 February 1968.
"Breaker Travel and Choice of Design Wave Height," C. J. Galvin, Jr., J. Waterways and Harbors Div., ASCE, Vol. 95, No. MW2, Proc. Paper 6569, pp. 175-200, May 1969.
"Breaker Type Classification on Three Laboratory Beaches," C. J. Galvin, Jr., J. Geophys. Res., Vol. 73, No. 12, pp. 3651-3659, 15 June 1968.

(5834)

LONGSHORE CURRENT VELOCITY REVIEW.

- (c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.
(d) Review of experimental theoretical, and field investigations.
(e) A search of the literature was made to collect all available data on longshore currents and all published relations for predicting longshore current velocity, for comparison purposes.
(g) The review of longshore current studies was published in Reviews of Geophysics, Volume 5, Aug. 1967, and the compilation of longshore current data was published as CERC Misc. Paper MP 2-67 in Mar. 1967. Other results of longshore current measurements made at Virginia Beach, Virginia, in 1966, were included in the paper listed in (h) below.
(h) "Modified Bruun Equation for Longshore Current Velocity," C. J. Galvin, Jr., CERC Lab. Rep. (unpublished), 11 pp., May 1969.

(5837)

NEW BERN STONE STUDY.

- (c) R. P. Savage, Asst. Chief, Research Division.
(d) Experimental; applied research.
(e) A rubble breakerwork with an armor layer of clayey limestone on a 1 on 1-1/2 slope is being tested for stability with non-breaking waves. Stone weights for the armor layer vary from 230 to 430 pounds and tests are being made with wave periods of 3.75, 5.60, and 7.87 seconds. Wave heights used vary from 2 to 4.5 feet. The tests are being conducted in a wave tank 635 feet long, 20 feet deep, and 15 feet wide.
(g) A porous marlstone from New Bern, North Carolina, has been tested in the CERC large wave tank and in the field. The tests were designed to determine the suitability of the New Bern stone for use as a cover layer in major coastal structures under wave attack. Rubble-mound breakerworks of the stone were tested in the CERC large wave tank in 1965 to determine stability coefficients (K_p) for use in field designs. In addition, weight losses of selected stones were recorded with the results indicating that the physical characteristics

(density, wearing qualities, and water uptake) vary considerably from stone to stone. The results indicated further that designs based on the K_p value recommended in CERC TR 4, Shore Protection, Planning and Design, for similar conditions would be somewhat conservative.

As a result of the weight losses observed in the large-wave tank tests, field tests were conducted to determine if the stone dissolves in sea water. Testing was carried out on an existing jetty at Fort Macon, North Carolina, from November 1967 to June 1969. Thirteen stones were placed alongside the jetty in the wave action zone, and were periodically removed, weighed, and replaced with rock weight losses being recorded. Results indicated that the stone from the New Bern quarry was variable with respect to surface texture, coloration, apparent durability, and water uptake, but failed to produce positive information on the mode or modes which caused stone weight losses. The results indicate that the use of New Bern stone in cover layers in an ocean climate should not be recommended. A final report is being written.

(6486)

LABORATORY TESTS OF RIPRAP STABILITY UNDER WAVE ACTION.

- (b) U. S. Army Engr. Div., Missouri River; also CERC Laboratory project.
(c) Thorndike Saville, Jr., Chief, Research Division.
(d) Experimental; applied research.
(e) Tests are carried out with various sizes and gradations of riprap to study the stability under instant wave action and various slopes of embankment. Tests are being made in three sizes of tanks; with waves varying from 0.2 to 6 feet in height, to show whether or not a scale effect exists. Slopes tested range from 1 on 2 to 1 on 8. Several of the tests have used actual rock from the Missouri River basin, to properly simulate roughness and interlocking characteristics of rock actually used on some of the large U. S. dams in the Missouri River basin. An overlay of tribars has also been tested at the several scales.
(g) Starting in November 1965 and continuing until November 1969 many laboratory tests were run at CERC to determine the stability of riprap in wave action. These tests were run for the Missouri River Division, U. S. Army Corps of Engineers. About 30 slopes protected by riprap were constructed and tested to failure in the large wave tank. About the same number were constructed and tested in the 85-foot medium wave tank, and about 70 in the 72-foot small wave tank. The armor material used for riprap included quarry stone (both limestone and quartzite), granitic fieldstone boulders, and concrete and leadite tribars. The median weight of the armor stones tested ranged from 0.03 pound in the small wave tank up to 390 pounds in the large wave tank; the weight of tribars tested ranged from 0.12 to 81 pounds. All of the tests in the large and medium tanks had embankment slopes of 1 on 2, 1 on 3, or 1 on 5. In the small wave tank these same embankment slopes were tested, plus two additional ones of 1 on 7 and 1 on 10. Zero-damage wave heights in the large tank ranged upward to over 5 feet in a number of tests. The most frequently used wave period in the large wave tank was 3.67 seconds with a water depth of 15 ft.
(h) A detailed report is being prepared by the Missouri River Division covering most of the riprap tests which were conducted for them by CERC.

(6993)

FIELD RESEARCH PIER.

- (c) Thorndike Saville, Jr., Chief, Research Division.
- (d) Experimental (field) and applied research.
- (e) A pier is to be constructed on Assateague Island to be used as a field station for the observation and collection of prototype data on wave, wind, and shore processes. The pier is designed to facilitate instrumentation and equipment necessary to observe and measure waves, currents, their effects on the shore materials, including shoreline changes.
- (g) Plans and specifications are under review and revision for the CERC Research Pier to be built on Assateague Island. Bids for the initial phase construction were advertised in January 1970; and presumably the construction should be completed in the spring of 1971. The Assateague Island location was chosen for several reasons: (1) a fairly straight unbroken, open coastline extends some 15 miles both north and south of the pier site; (2) 4-hour drive from the CERC office; and (3) the absence of shoreline structures. Field studies now planned include: wave runup, wave setup, littoral current, breaker height, breaker depth and breaker travel distance relationships, and tests of the amount of sediment in suspension.

(6994)

INLET AND ESTUARY DYNAMICS.

- (c) R. P. Savage, Asst. Chief, Research Division.
- (d) Theoretical and experimental, development.
- (e) This project consists of research and development on inlet and estuary dynamics including theoretical, laboratory, and field studies of the tidal hydraulics, shoaling, bank erosion, pollution and flushing, and the interaction of ocean, inlet and estuary factors. It also includes the functional design of structures to stabilize or modify various factors of the ocean-inlet-estuary system. Research will provide an improved understanding of inlet and estuarine dynamics in particular tidal hydraulic phenomena, shoaling, bank erosion, pollution and flushing and effects of and to adjacent shores.
- (g) A study was continued at a location in Chesapeake Bay to relate erosion rates of different types of shore characteristics (bluff, beach, dune, bulkhead) to incident wave and water level conditions. Periodic surveys are obtained. It is planned to extend the study to other areas with different soil types.
- Also, an office study of inlets on U. S. coastlines was begun in the last quarter of 1969. A catalog has been prepared of copies of inlets from USCGS charts, mostly of 1:80,000 scale. The catalog is restricted to inlets which appear to have at least one side bounded by alluvial material (ruling out inlets between rocky points). The purpose of this study is to assemble the known facts concerning inlets in alluvial material as background for understanding the mechanics of these inlets. Of special interest in this study is the seaward offset of barrier islands where they meet at inlets.
- (h) "A Model Study of the Entrance Channel, Depoe Bay, Oregon," John P. Ahrens, Coastal Engrg. Res. Ctr. Tech. Memo. No. 23, Sept. 1967.

(6995)

COASTAL ECOLOGY STUDY.

- (c) Kenneth W. Osborn, Marine Biologist, Research Division.
- (d) Field investigation, applied research.
- (e) Five "ecological problem areas" relating to engineering activities are being investigated: off-

shore construction, offshore dredging, coastal waste disposal, estuarine dredging, and hurricane and ocean storm protection structures and activities. For each "ecological problem area," a planning document will be prepared and will include, (1) a highly selective annotated bibliography, (2) the expected ecological consequences, (3) the current state of knowledge of ecological effects, and (4) additional research necessary to provide knowledge of ecological effects where that knowledge is missing.

In advance of completion of these planning studies, several field studies have been initiated as follows: 1. Offshore Dredging: An ecological monitoring study of a beach erosion control project utilizing an offshore borrow area for the source of sand. 2. Coastal Waste Disposal: A large-scale study of the ecological effects of waste disposal in the New York Bight (funded from other sources) is being supervised. An intensive study on the development of techniques for more sophisticated analyses of trace (metal) elements in waste materials, and determinations of concentrations of these elements in wastes both from treatment plants and in the New York Bight. 3. Estuarine Dredging: A pilot study on the stabilization and productive use of dredge spoil utilizing marsh grass.

- (h) "Site Visit Report, Stony Brook and Sandy Hook," Smithsonian Institution Feb. 20, 1970 (the first of a series of reports to the U. S. Army Corps of Engineers from the Scientific Advisory Committee for the Corps' Offshore Waste Disposal Study, organized by the Smithsonian Institution at the request of CERC to provide advice and counsel to the Corps and to assist in evaluating the results of the study as it progresses).
- "The Effects of Waste Disposal in the New York Bight -- Interim Report for January 1, 1970," Sandy Hook Marine Lab., U. S. Dept. of Interior, Dec. 3, 1969.
- "Preliminary Analyses of Urban Wastes, New York Metropolitan Region," M. Grant Gross, Tech. Rep. No. 5, Marine Sciences Res. Center, State Univ. of New York, Stony Brook, N. Y., March 1970.

(6996)

REVIEW OF OCEAN WAVE ANALYSIS TECHNIQUES.

- (c) Dr. D. Lee Harris, Chief, Oceanography Branch.
- (d) Theoretical, basic research.
- (e) This study consists of theoretical, empirical and experimental review and evaluation of wave analysis approaches, including the "significant wave" and "wave spectra" methods. The purpose is to select and develop those analysis methods and techniques which improve the directness of application and accuracy of design parameters.
- (g) The standard form of wave record analysis in coastal engineering is to assign a "significant wave height and period" to each record. Two definitions of the "significant wave height" are widely used. According to the earliest usage it is defined as the average height of the one-third highest waves. Some later workers define it as four times the root-mean-square departure of the water surface from its mean position. Several definitions have been employed for the "significant period." The earliest, as applied to wave records identifies the "significant wave period" as the average period of the one-third highest waves. Other definitions have been -- the average period of the more prominent waves in the record -- or the average period at which the water surface rises from below to above the mean water level. This descriptive system uses only two parameters to describe a complicated statisti-

cal system. The use of digital computers makes a more complete description, an energy density spectrum, feasible. The relationship between the older descriptions and spectral descriptions is being investigated.

(6997)

WAVE HEIGHT VARIABILITY IN THE SHORE PROCESSES TEST BASIN (SPTB).

(c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.

(d) Experimental, development.

(e) The purpose of the wave height variability tests is to examine the cause of temporal and spatial variability of wave heights observed in laboratory wave basins. Mechanisms which may cause variations in wave height are seiche of the whole water body, wave reflection from beaches and training walls, and wave refraction and diffraction. All of these are being investigated.

(g) Seiche has been eliminated as a cause of significant wave height variability for the conditions that are usually tested in the CERC basin. Wave refraction and diffraction have been shown to be causes of wave height variability which can be largely predicted from theoretical considerations. The largest and least predictable factor producing wave height variability has been found to be wave reflection from the changing sand beach profile. Reflected wave heights of up to 20% of the incident wave height have been measured in a series of continuing tests.

(h) "Recommendations to Reduce Leakage in the 96-Foot Tank," L. W. Tenney, CERC Lab. Rep. (Unpublished), 19 pp., 17 March 1969.

"Wave Height Variability in Inclosed Basins," C. J. Galvin, Jr., CERC Lab. Rep. (Unpublished), 40 pp., 11 July 1969.

(6998)

COOPERATIVE SURF OBSERVATION PROGRAM (COSOP).

(c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.

(d) Field investigation, development.

(e) The purpose of the CERC-Coast Guard Cooperative Surf Observation Program (COSOP) is to collect visually estimated wave data from around the coasts of the United States for use in developing a wave climatology of U. S. coastlines, from which wave statistics of engineering usefulness (extreme heights, percent of workable days, seasonal variation, dominant direction, etc.) may be extracted. Data are collected at 4-hour intervals, visibility permitting, at cooperating stations by Coast Guard personnel. Measurements are made just outside the surf zone and data include wave height, period, direction, and breaker type; all recorded on forms which are mailed weekly to CERC where they are checked and filed for eventual analysis.

(g) CERC has analyzed all data contributed between 1954 and the end of 1965 (over 300,000 observations), and three reports on this data are in various stages of completion. A total of 30 stations have cooperated with COSOP over the past 16 years, of which 14 are still contributing data. Analysis of the data collected from 1954 through 1965 has resulted in two laboratory reports describing general features of the data and tabulating yearly and monthly averages of height and period. The data show marked differences in wave characteristics between the east and west coasts of the U. S., and usually good agreement between data from adjacent stations with similar exposures on the same coast. Wave heights and periods average about 1.5 feet and 6 seconds on the east coast,

and 3 feet and 12 seconds on the west coast. Wave period shows little change from month to month but wave height exhibits noticeable seasonal change.

(h) "Nearshore Visual Wave Observations for United States Coastlines," C. J. Galvin, Jr., D. G. Dumm, Jr., Barry R. Sims, and L. W. Tenney, CERC Lab. Rep. (Unpublished), 36 pp., 9 April 1969. "Surf on U. S. Coastline," CERC Lab. Rep., C. J. Galvin, Jr., and W. N. Seelig (Unpublished), 12 pp., 8 August 1969.

(6999)

SECONDARY WAVES.

(c) Dr. C. J. Galvin, Jr., Oceanographer, Research Division.

(d) Experimental, basic research.

(e) The purpose of this study is to experimentally determine the shapes of water waves generated by the approximately sinusoidal motion of a piston-type wave generator when water depth and generator period and stroke are varied over as wide a range as possible. Water surface profiles are measured with resistance wave gages and their shapes classified and related to hydrodynamic theory. The study extends into conditions where the waves break.

(g) Steep waves in shallow water have non-linear properties which cause them to disperse into two or more waves of differing amplitudes and speeds, with speeds dependent on amplitudes. Both experimental results and numerical solutions show that the larger of the waves eventually overtakes, interacts with, and passes through the smaller ones. During interaction the net crest elevation of the two 'superimposed' waves is less than the elevation of the larger when isolated. Interacting waves eventually assume a form nearly identical to the initially generated form. Conditions in the region $d/L = 0.09$, $H/d = 0.05$ produced multiple wave crests from an original single crest. The number of crests increased as d/L decreased and was relatively independent of H/d . At lowest (H/d , d/L) conditions, interactions resulted in confused wave forms. Regular periodic waves were limited to the remaining region, largely $0.3 \geq d/L \geq 0.09$.

Test results have shown that the secondary wave effect is primarily a function of the water depth to wave length ratio, and not one produced directly by wave generator motions. Tests have also shown that secondary wave phenomenon occurs regardless of scale, with tests in the large wave tank repeating results obtained in a small wave flume.

(h) "Finite-Amplitude Shallow-Water Waves of Periodically Recurring Form," C. J. Galvin, Jr., CERC Lab. Rep. (Unpublished), 21 pp., 11 March 1968. "Secondary Waves as Solitons," and "Shapes of Unbroken, Periodic, Gravity Water Waves," C. J. Galvin, Jr., Trans. Amer. Geophys. Union, V. 49, March 1968. "Secondary Wave Tests on a Slope and Shelf in the CERC Large Wave Tank," R. P. Savage, CERC Lab. Rep. (Unpublished).

DEPARTMENT OF THE ARMY, DIVISION HYDRAULIC LABORATORY, NORTH PACIFIC DIVISION, CORPS OF ENGINEERS, Bonneville, Oregon 97008. H. P. Theus, Director.

(405)

GENERAL MODEL STUDY OF ICE HARBOR DAM, SNAKE RIVER, WASHINGTON.

(b) U. S. Army Engr. Dist., Walla Walla.

(d) Experimental; for design.

(e) Ice Harbor Dam is located on the Snake River 9.7 miles upstream from the junction of the Snake and Columbia Rivers. Principal features include a powerhouse for six 90,000-kw generating units (initial installation is three units) a concrete gravity spillway with ten 50-foot wide bays, a navigation lock with net clear dimensions of 86 by 675 ft. and a maximum single lift of 103 ft., and facilities for passing fish upstream over the dam. The purpose of the general model study was to determine flow conditions before, during, and after construction of the project. A 1:100-scale, fixed-bed model reproduced pertinent structures and 2.7 miles of Snake River channel adjacent to the dam.

(f) Tests completed; final report in preparation.
(g) Realignment of the first-stage cofferdam was required to reduce backwater effect and to lower water-surface elevations along the steel cells. A system of rock groins along the shore opposite the first-step cofferdam was developed to aid fish migrations. Satisfactory flow conditions during second-stage construction were obtained by realigning the downstream leg of the cofferdam, increasing excavation in the upstream approach, and passing part of the discharge through the skeleton powerhouse units. Investigation of tailrace alignments indicated that a larger tailrace would provide optimum head on the powerhouse. Tailwater variations and wave action along the powerhouse and at the fishway entrances were minimized by revising the navigation lock outlet to direct flow downstream. Uniform or crowned operation of the spillway gates provided satisfactory flow conditions in the stilling basin and at adjacent fishway entrances.

(407)

MODEL STUDY OF NAVIGATION LOCK FOR ICE HARBOR DAM, SNAKE RIVER, WASHINGTON.

(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) See (405) for description of project. The hydraulic system for filling the lock chamber consists of wall intake manifolds, a longitudinal culvert in each sidewall, 12- by 14-foot, reverse-mounted tainter culvert valves, and wall discharge manifolds leading to five bottom laterals. Twelve ports, six on each side, discharge from each bottom lateral; ports in adjacent laterals are offset for clearance of opposing jets. The total area of ports is 1.2 times culvert area at the valves. In emptying, flow enters the lateral ports and passes through 12- by 14-foot culverts which bend 90 degrees just upstream from the vertical-lift downstream lock gate. Flow is released from a river outlet located 450 ft. downstream from the stilling basin. The purposes of the model study were to check the original design and to develop improvements if necessary. A section of culvert adjacent to and including a single bottom lateral was reproduced in a 1:16-scale model. Principal features of the lock approaches, lock chamber, and hydraulic systems were reproduced in a 1:25-scale model.
(f) Tests completed; final report in preparation.
(g) Tests in the 1:16-scale model indicated that revisions of alignment and taper improved distribution of flow in the upstream floor lateral. Similar revisions had no significant effect in the four downstream laterals. Flow distribution was improved by a splitter at the downstream end of the laterals. Pressures downstream from the right filling valve and in 90-degree bends of original design were lower than desired, and hawser forces on barge tows in the lock chamber

were excessive. Pressures and hawser forces were satisfactory in the final design. At maximum initial head, 103 ft., the lock chamber filled in 11 min. and emptied in 13 min. when the valves were opened in 4.0 min. (filling) and 2.2 min. (emptying). Maximum hawser forces on a barge tow with displacement of 11,040 tons varied from 4 to 6 tons.

(2662)

GENERAL MODEL STUDY OF JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) John Day Dam is located on the Columbia River, 25 miles upstream from The Dalles, Oregon. The reservoir formed by the 5900-foot long dam provides 76 miles of slack water for navigation upstream to McNary Dam and 500,000 acre-feet of flood storage. The spillway, designed for a flow of 2,250,000 cfs, consists of twenty 50-foot wide bays separated by 12-foot wide piers. The crest gates (tainter), each 50 feet wide by 58.5 feet high, are operated by individual electric hoists. Sixteen 135,000 KW Kaplan turbines are to be installed initially in the powerhouse; ultimate installation 20 units with total capacity of 2,700,000 KW. The 86- by 675-foot navigation lock has a maximum single lift of 113 feet. Fish facilities include a powerhouse collection system, auxiliary water supply systems, and a 24-foot wide fish ladder with main sections sloped 1 on 10 on each side of the river. The purposes of the model study were to provide information concerning diversion methods, conditions for navigation and fish passage, water-surface elevations, and flow patterns for each phase of construction. An 1:80-scale model reproduced 2.9 miles of Columbia River channel and pertinent overbank topography adjacent to the dam.

(f) Tests completed; final report in preparation.
(g) Satisfactory designs were developed for first- and second-step cofferdams. Although flow patterns adjacent to the main structures were satisfactory, realignment of the lock approach channels was necessary, and increased excavation in the powerhouse tailrace was indicated. A spillway operation schedule was developed to provide satisfactory conditions at the north fishway entrance and to minimize return flow into the stilling basin. Flow conditions adjacent to the adopted structures were satisfactory for all river discharges and all methods of project operation that were studied.

(2666)

MODEL STUDY OF FISH LADDERS FOR ICE HARBOR DAM, SNAKE RIVER, WASHINGTON.

(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) See (405) for description of project. The facilities for fish include a powerhouse collection system and a fish ladder with auxiliary water supply system on both sides of the river. The main portion of the north fish ladder is 16 feet wide and has a floor slope of 1 on 10. The 24-foot wide south fish ladder slopes 1 on 16.
(f) Tests completed; final report in preparation.
(g) Test results indicated that surge would occur in the normal operating range of the 24-foot wide south fish ladder unless weirs with approximately sharp-edged crests were used. Surge was reduced by a contracted weir. A 16-foot wide ladder with 1-on-10 slope was developed in which flow conditions were comparable to those with a slope of 1 on 16. This was accomplished by

using a 6-foot long nonoverflow section on the center of each weir and by fins which extended 1.5 feet upstream from each end of the nonoverflow section. Uniform head drops in the control sections were obtained by varying the size and spacing of orifices in alternate nonoverflow baffles (24-foot ladder), or by varying the spacing of orifices in each baffle (16-foot ladder).

(3577)

GENERAL MODEL STUDY OF LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (c) Experimental; for design.
- (e) Lower Monumental Dam is located at Snake River mile 41.6, about 32 miles upstream from Ice Harbor Dam. Principal features include a powerhouse for six generating units (ultimate installation), a navigation lock with net clear dimensions of 86 by 675 foot and a maximum single lift of 103 feet, an 8-bay gravity spillway, and a 16-foot wide fish ladder on each side of the river. The purpose of the model study was to investigate flow conditions that might occur during and after construction of the project. A 1:100-scale model reproduced approximately 2.4 miles of Snake River bed and overbank topography at the dam site.
- (f) Tests completed; final report in preparation.
- (g) The model study indicated that proposed limits for first-step excavation along the right bank were not adequate. Revisions in alignment and height of first-step cofferdam cells were required. Problems concerning fish passage were solved for each stage of construction. Final designs for all features of the project were developed and tested under anticipated prototype operating conditions.

(3578)

MODEL STUDY OF FISH LADDERS FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (c) Experimental; for design.
- (e) A 1:10-scale model was used for tests of the 24-foot wide, 1-on-10 sloped fish ladders for John Day Dam.
- (f) Completed.
- (h) "Fish Ladders for John Day Dam, Columbia River, Oregon and Washington," R. L. Johnson and L. Z. Perkins, Div. Hydr. Lab. Tech. Rept. No. 103-1, Dec. 1968.

(4380)

MODEL STUDY OF SPILLWAY FOR GREEN PETER DAM, MIDDLE SANTIAM RIVER, OREGON.

- (b) U. S. Army Engr. Dist., Portland.
- (c) Experimental; for design.
- (e) The 2-bay spillway, flanking abutments, outlet conduits, stilling basin, fish collection system, powerhouse tailrace, and about 1540 feet and 1620 feet of spillway approach and exit channels, respectively, were reproduced in a 1:50-scale model. The model was used to check the adequacy of designs for the spillway crest, piers, abutments, and gate trunnion supports, outlet eye-brows, stilling basin, and training wall between the stilling basin and powerhouse tailrace.
- (f) Completed.
- (h) "Spillway and Fish-Passage Facilities for Green Peter Reservoir, Middle Santiam River, Oregon," Div. Hydr. Lab. Tech. Rept. No. 107-1, Aug. 1965.

(4504)

GENERAL MODEL STUDY OF LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.

(d) Experimental; for design.

- (e) Little Goose Dam, at Snake River mile 70.3, is the third in a series of multiple-purpose dams being constructed above the mouth of Snake River for power, navigation, and other uses. Salient features include an 8-bay spillway, a navigation lock 86 feet wide by 675 feet long (maximum lift 101 feet), a powerhouse for six units (initial installation three 135,000-KW generators), and a 20-foot wide fish ladder on the south shore. A model study was necessary to determine minimum excavation requirements, to verify structure locations, and to check the overall effects of these structures on navigation, power generation, and fish passage. A general model, constructed to a linear scale ratio of 1:100, reproduced the river channel and pertinent overbank areas for 1.35 miles upstream and 1.90 miles downstream from the project axis.
- (f) Tests completed; final report in preparation.
- (g) Tests of the first diversion stage led to relocation of the temporary fishway, use of rock groins as velocity reducers, savings in channel excavation, fewer cofferdam cells, and lower embankments. Proposed excavation for second-step diversion was reduced. Approach flow into the proposed main structures was satisfactory. Excavation in the tailrace could be raised 20 feet without loss of head on the powerhouse. A short spur dike to support transmission line towers also eliminated objectionable flow across the downstream lock approach. Performance of the fish collection system was improved by moving the north fishway entrance upstream 20 feet and extending the right training wall 90 feet by means of an earthfill dike. Flow patterns, velocities, and water-surface elevations for alternative methods of operating the project were determined.

(4505)

MODEL STUDY OF FISHWAY DIFFUSERS FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (c) Experimental; for design.
- (e) An existing 1:8-scale fishway diffuser model was revised so that two diffusion chambers were supplied by a single riser from the conduit. Included in the model were diffusers 3 and 4 and the common distribution well, the supply conduit, and a portion of the 16-foot wide south shore fish ladder that carried all flow which passed through the diffusion chambers. In the original design, a 7-inch wide control orifice was located 3.5 feet above the diffuser well floor, and 1.5 foot high ports admitted flow into the respective diffusion chambers. The information desired from this model includes: the orifice size required to provide 48 cfs through each diffuser with a head of 2 feet (supply conduit grade line minus tailwater elevation), a submergence of 4 feet (supply conduit grade line minus elevation of downstream weir adjacent to diffuser 3), and a conduit flow of 500 cfs; a family of rating curves for heads of from 0.5 feet to 6.0 feet and various submergences; and the effect on diffuser discharge of varying the conduit flow from about 50 cfs (only one diffuser) to 750 cfs while a constant head is maintained on the test diffuser.
- (f) Tests completed; final report in preparation.
- (g) Two diffuser floor plans and 12 orifice arrangements were tested in efforts to obtain uniform distribution of diffuser flow into the fish ladder. The most satisfactory arrangement was selected from the test results.

- (4506)
MODEL STUDY OF FINGERLING COLLECTOR FOR GREEN PETER DAM, MIDDLE SANTIAM RIVER, OREGON.
(b) U. S. Army Engr. Dist., Portland.
(d) Experimental; for design.
(e) Two undistorted hydraulic models are being used for studies of facilities for downstream migration of fingerling salmon and steelhead trout at Green Peter Dam. The proposed facility is composed of an entrance horn, vertical adjustable-height riser, separator, flow distribution control device, trough, flexible hose, transverse pipe system, and outlet pipe followed by a flume into the tailwater. The collector will be located on the upstream face of the dam at the focal point of reservoir discharge. Its 20-foot high horn will collect fish near the water surface with a minimum submergence over its top of 5 feet and a maximum submergence at its bottom of 40 feet. About 200 cfs will enter the horn and carry migrating fish inward, upward, and across a separator screen (a 10- by 20-foot perforated plate) covering the compartmented flow distribution device through which from 190 to 194 cfs will pass vertically into a collector well and then be pumped back to the reservoir. Fish in the remaining 6 to 10 cfs will be carried from the separator screen through a flexible hose attached to laterals through the dam and thence by open channel flow to the tailrace. A trash boom at the upstream face of the dam will prevent small floating and suspended debris from entering the fingerling collector.
- (f) Completed.
(h) See (4380).

- (5068)
MODEL STUDY OF SPILLWAY FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.
(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) See (4504) for description of project. A 3-bay section of the 8-bay spillway and stilling basin was reproduced in a 1:42.45-scale model. The purposes of the tests were to check performance of the original spillway and to develop revisions that would improve performance or reduce construction and maintenance costs.
(f) Tests completed; final report in preparation.
(g) Discharge coefficient with piers (C_p) was 4.054 at the design spillway flow of 850,000 cfs. Pressures on the piers just downstream from the gate slots were -2 feet of water at 450,000 cfs and as low as -27 feet of water at the spillway design discharge. Tailwater-jump data indicated that the stilling basin should be lowered at least 5 feet. A satisfactory horizontal stilling basin was developed in the model, but unusual artesian conditions at the site would have required an extensive drainage system under the 5-foot thick basin slab. To eliminate the heavy slab and costly drainage system, a modified Angostura bucket was developed in the model.

- (5069)
MODEL STUDY OF NAVIGATION LOCK FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.
(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) See (4504) for description of project. The intake manifolds, longitudinal culverts (both in right wall), lock chamber, split lateral filling and emptying system, outlet culverts, and portions of the approach and outlet areas were reproduced in a 1:25-scale model. An alternative method for distributing flow to the lateral culverts from a central junction chamber was studied

- in an auxiliary 1:25-scale model of the lock chamber. The purposes of the studies were to check the suitability of the original design and to develop improvements if necessary.
(f) Tests completed; final report in preparation.
(g) The lock chamber of final design can be filled in 11.4 min. and emptied in 12.8 min. under an initial head of 101 feet. Average forces on an 8-barge tow will not exceed 5 tons. A satisfactory hydraulic system with junction chamber and longitudinal port manifolds inside the lock chamber was developed in the auxiliary model but not tested in the lock model.

- (5070)
MODEL STUDY OF SPILLWAY FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.
(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) Dworshak Dam, on the North Fork of Clearwater River will furnish 400,000 KW of power from three units (initial installation) and, ultimately, 1,060,000 KW from six units. The spillway consists of two 50-foot wide bays, with crest at elevation 1545, a chute, and a 114-foot wide, 271-foot long stilling basin at elevation 931. Three 9- by 12.5-foot regulating outlets, upstream from the tainter valves, and 11 by 17 feet downstream from valves, discharge on the spillway chute. Total capacity of the spillway and regulating outlets is 221,000 cfs at pool elevation 1604.9. Approximately 1.6 miles of river channel and pertinent overbank topography were reproduced in a 1:50-scale model to study the cofferdam and diversion tunnel. A section of forebay, the spillway, regulating outlets, stilling basin, powerhouse, tailrace, and exit channel were reproduced to determine hydraulic characteristics of these elements.
(f) Tests completed; final report in preparation.
(g) Flow conditions with the original diversion tunnel entrance, tunnel alignment, and outlet channel were unsatisfactory. The tunnel entrance was moved upstream and tunnel curvature was reduced. Problems concerning log and fish passage, closure of tunnel entrance, and construction of diversion fills were solved in the model. Severe negative pressures on the pier, abutments, and crest, rooster tail in the chute, and critical flow in the exit channel indicated that original designs for these elements were not adequate. Improved designs for the abutment curves, side conduits, lower chute, stilling basin, and fish facilities (pumphouse intakes and fish entrances) were developed and checked in the model.

- (5071)
GENERAL MODEL STUDY OF LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON.
(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) Lower Granite Dam, at Snake River mile 107.5, is 37.2 miles upstream from Little Goose Dam. The 8-bay spillway, with 50- by 60.5-foot control gates (tainter) and the 498-foot wide, 167-foot long nonbaffled stilling basin are designed for a maximum discharge of 850,000 cfs. The 6-unit powerhouse will have a capacity of 810,000 KW; initial installation 405,000 KW from three units. The 86- by 675-foot navigation lock will have a maximum single lift of 105 feet. Fish facilities include a powerhouse collection system, three pumps for additional attraction flow (2550 cfs) and one 20-foot wide fish ladder with floor slope of 1 on 10. A 1:100-scale general model reproduced the riverbed and pertinent overbank topo-

- graphy between Snake River miles 106.1 and 108.9 and successive phases of construction. Construction stages, powerhouse tailrace limits and depths, navigation lock approaches, flow conditions affecting fish passage, and project operations were to be studied in the model.
- (g) The first-step cofferdam and diversion channel were satisfactory after the channel entrance was modified and rock groins to aid fish migrations were added. Embankment and excavation limits for construction phases were determined. The effects of several stages of erosion downstream from the original stilling basin were investigated, and an improved basin design was developed with estimated maximum erosion in the tailrace. Satisfactory energy dissipation was obtained with the stilling basin raised 4 feet and a 9-foot end sill (originally 11 feet high). An undesirable eddy existed between the north fishway entrance and the navigation lock wall. Several combinations of walls, fills, and training wall extensions were tried in efforts to develop satisfactory conditions at the north fishway entrance.
- (5315)
MODEL STUDY OF REGULATING OUTLETS FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.
(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) See (5070) for description of project. The three regulating outlets, with intakes at elevation 1350, will operate under heads of from 95 feet at minimum pool elevation 1445 to 254.9 feet at maximum pool elevation 1604.9. Total outlet capacity will be 40,000 cfs at pool elevation 1604.9. Pressures, flow conditions, and discharge relationships were observed in a 1:25-scale sectional model that reproduced a portion of the forebay, the right conduit, and a section of the spillway chute. The purpose of the study was to check the adequacy of the original design and to develop revisions if necessary.
(f) Tests completed; final report in preparation.
(g) Four designs for a bellmouthed intake were studied. The center line of the original (plan A) intake was skewed 10° vertically and 5° -38' horizontally, and the bellmouth surfaces were formed by simple ellipses. The plan B bellmouth was formed by compound elliptical curves on all four sides. The bottom curve extended beyond the headwall, and the bulkhead seat was recessed into the upstream end of the curve. The compound curves were retained in plan C (without horizontal skew) and plan D (without horizontal or vertical skew). Pressures at the corners of intake plans A to C were within the range of cavitation when the control valve was fully opened (12.5 feet) under a head of 250 feet. Pressures were satisfactory when the valve was 12.0 feet open (12.3 feet in plan C). Pressures in the plan D bellmouth were satisfactory. However, the plan D bellmouth, which extended beyond the face of the dam, would have complicated design and use of the unwatering bulkhead. An alternative design, which placed the bellmouth inside the dam, was developed in the Libby and Dworshak conduits model study.
- (5316)
MODEL STUDY OF FISH LADDER FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.
(b) U. S. Army Engr. Dist., Walla Walla.
(d) Experimental; for design.
(e) See (4504) for description of project. A 1:10-scale model was used for tests of a 20-foot wide fish ladder with floor slope of 1 on 10.
(f) Tests completed; final report in preparation.
- (g) Velocities, flow patterns, and discharge relationships were determined in typical pools, flow-control section, and slot-type counting station. Flow within the typical pools and counting station of original design was satisfactory. A minor adjustment of orifices in the uppermost bulkhead of the flow-control section was required.
- (5317)
MODEL STUDY OF COLUMBIA RIVER, OAK POINT TO VANCOUVER, WASHINGTON.
(b) U. S. Army Engr. Dist., Portland.
(d) Experimental; for design.
(e) The project will increase the navigation channel width from 500 feet to 600 feet and the depth from 35 to 40 feet between Columbia River miles 52 to 109 and from the mouth of Willamette River to Portland, Oregon. Project depths and widths will be maintained by a system of pile dikes and by dredging. Five separate movable-bed models with 1:300 horizontal and 1:100 vertical scales will be required to cover improvements in the Columbia River. The models will be used initially to check plans for constructing and maintaining the 40-foot channel. Later the models will be used to check operation and maintenance activities and new construction. The first two models include river miles 53 to 65 and 64 to 78, respectively. Work on the remaining three models has not begun.
(g) Shoaling indexes, based on results with an uncontrolled 40-foot deep navigation channel, were determined for each improvement plan tested in the models. Satisfactory plans are being developed for all problem reaches covered by both models. Alternative proposals, which would be more acceptable to local interests in the Longview-Rainier area (mile 66), were tested and the benefits of these plans were determined.
- (5318)
MODEL STUDY OF POWERHOUSE SKELETON UNITS FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.
(b) U. S. Army Engr. Dist., Portland.
(d) Experimental; for design.
(e) See (2662) for description of project. Proposed changes in the skeletonized powerhouse units called for placement of as much concrete in the powerhouse draft tubes as diversion requirements would allow. The proposed skeleton bay differed from the original contract plan and from that at the Dalles Dam, the only unit that had been model tested. The changes, which were necessary to meet an accelerated construction schedule, might have affected designs for powerhouses at Lower Monumental and Little Goose Projects. A typical skeletonized unit of the type to be used for diversion was reproduced to a scale of 1:25 in a flume with glass sides that allowed observation of flow within the test unit.
(f) Tests completed; final report in preparation.
(g) Discharge capacity of the first skeleton unit tested was inadequate. Improved designs were developed for units 11 to 19 (with drainage tunnel over draft tube) and for special unit 20 (without drainage tunnel).
- (7107)
MODEL STUDY OF SECOND POWERHOUSE FOR BONNEVILLE DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.
(b) U. S. Army Engr. Dist., Portland.
(d) Experimental; for design.
(e) The existing project includes an 18-bay spillway with vertical gates lifted by 350-ton gantry cranes, a powerhouse with total rated capacity of 518,000 KW from 10 main units and one station

service area, a navigation lock with net clear dimensions of 76 by 500 feet, and fish facilities on each side of the river. Head on the project varies between 30 and 70 feet. From four to ten additional units are proposed to utilize increased storage and peaking operations at upriver projects. A 1:100-scale fixed-bed model reproduces the existing structures, riverbed, and pertinent overbank topography between river miles 142.2 and 146.8. A remote-controlled towboat and tow are used to evaluate the effect of additional power units on navigation. The purpose of the study is to confirm the site chosen for the second powerhouse and to study flow conditions affecting fish passage, navigation, and head on the project.

- (g) Tests of two structures and excavation plans were completed. Six additional powerhouse units and a new 86- by 675-foot navigation lock on the Oregon shore were included in the first plan. Excavation requirements for optimum head losses upstream from powerhouse and for satisfactory flow conditions in the lock approaches were determined for this plan. The second plan provided for eight additional units on the Oregon shore and a new lock on the Washington shore. Excavation requirements and flow conditions upstream from the powerhouse and conditions in the upstream approach to the navigation lock were investigated with the second plan.

(7108)

MODEL STUDY OF SPILLWAY GATE MODIFICATION FOR BONNEVILLE DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

- (b) U. S. Army Engr. Dist., Portland.
- (d) Experimental; for design.
- (e) See preceding report for description of project. Additional pondage at Bonneville Dam will be required to accommodate water released by future increased power peaking of upstream dams. It is proposed that the Bonneville spillway gates be made 10 feet higher to provide the necessary pondage and that some of the gates be motorized to allow remote control. The present gates cannot be operated under certain conditions because of vibration and a tendency to bounce. Remote control of spillway gates requires no known restrictions on spillway operation. A 1:25-scale model included one spillway bay, two half piers, one spillway gate, and a 60-foot wide section of stilling basin and adjacent approaches. The gate was free to move vertically in the gate slots. The purposes of the study were to check performance of the existing gate bottom and to develop an improved design.
- (f) Tests completed; final report in preparation.
- (g) The original gate bottom and six alternative shapes were investigated. Flow control shifted rapidly between the bottom seal and upstream face of the existing gate. The shifting control and resulting changing forces on the gate bottom made the gate vibrate vertically in the gate slots. Alternative gate shapes had varied vertical distances between the bottom of the upper face and the horizontal seal. A distance of 2.61 feet between the bottom seal and the bottom of the upstream skin plate was recommended. With this design, vertical vibrations of the prototype gate will be negligible.

(7109)

MODEL STUDY OF INCREASED POOL ELEVATION AT SPILLWAY OF CHIEF JOSEPH DAM, COLUMBIA RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Seattle.
- (d) Experimental; for design.
- (e) The existing project, located 51 miles below Grand Coulee Dam includes an excavated channel

leading to an intake for 27 penstocks, a 20-unit powerhouse (initial installation 16 Francis turbines), and a spillway with nineteen 40-foot wide bays surmounted by 9-foot wide piers and 56.2-foot high tainter gates. The spillway ogee was designed for a head of 41.6 feet on the crest, or 75 percent of the computed maximum total head of 55.4 feet at the project design flow of 1,250,000 cfs. Construction of a third powerhouse at Grand Coulee Dam will require additional storage and power units at Chief Joseph to use the increased flow. Present plans include raising the Chief Joseph pool from existing elevation 946 to maximum elevation 970, or up to 1.7 times the design head. Preliminary data on surge characteristics at the spillway were obtained in an existing spillway model that contained a standard high dam crest and piers with elliptical noses. The most suitable modifications will be studied in a 1:43.35-scale model of the existing Chief Joseph spillway and stilling basin. The model study will show how the existing structures must be revised to maintain satisfactory flow conditions and pressures under higher operating heads.

- (f) Preliminary tests were completed. Design and construction of the spillway model were begun.

(7110)

MODEL STUDY OF CONDUIT ENTRANCES FOR DWORSHAK DAM, IDAHO, AND LIBBY DAM, MONTANA.

- (b) U. S. Army Engr. Dist., Walla Walla and Seattle.
- (d) Experimental; for design.
- (e) Normal reservoir outflows at Dworshak and Libby Dams will discharge on the respective spillway chutes through conduits that operate under heads up to 250 feet on the regulating valves (tainter). Although conduit dimensions upstream from the valves differ (9 by 12.5 feet at Dworshak and 10 by 17 feet at Libby), the same type of bell-mouthed intake will be used at both dams. The tentatively adopted "no-skew" intakes that were developed during the Dworshak conduit model study extended upstream beyond the face of the dam. This would have complicated design and use of unwatering bulkheads. A regulating conduit with streamlined entrance and a portion of forebay were reproduced in a 1:20-scale model for measurements of discharges, pressures, and other data. The purpose of the study was to develop revisions that could be used at Dworshak, Libby, or other projects.
- (f) Tests completed; final report in preparation.
- (g) Three designs for short, skewed, bell-mouthed entrances for the Dworshak and Libby conduits were tested. Satisfactory plans for both entrances were developed.
- (h) Engineer Technical Letter No. 111-2-41, "Skewed Entrance for High-Head Conduits," Dept. of the Army, Office of the Chief of Engrs., Wash., D. C., 9 May 1968.

(7111)

MODEL STUDY OF FISHWAY DIFFUSER FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (5070) for description of project. Adult fish will be attracted into a collection channel leading to a holding pool from which they will be transported to a hatchery, to the reservoir, or to another stream. Water for operation of the fish facilities will be pumped from tailwater, and distributed by means of six diffusion chambers into the collection system, holding pool, and hopper pool. A typical diffusion chamber and portions of the adjoining supply conduit and

collection channel were reproduced in a 1:10-scale model. Flow in the conduit varied from 100 to 480 cfs, diffuser discharge was 60 cfs, and a differential head of 2.5 feet existed between the supply conduit and collection channel. The purposes of the study were to check the adequacy of a typical diffusion chamber and to develop revisions if required.

- (f) Tests completed; final report in preparation.
- (g) Orifice gate settings that would produce 60 cfs per diffuser for a head of 2.5 feet were determined. Modifications of the sloping floor and baffle adjacent to the left wall, roof corner, and distance from inflow orifice to upstream wall of diffusion chamber were investigated.

(7112)

MODEL STUDY OF HATCHERY JET HEADER FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (5070) for description of project. A new type of rearing pond, developed by the U. S. Fish and Wildlife Service, will be adapted for use at the Dworshak fish hatchery. Circulation in each pond will be provided by two jet headers that discharge between 70 and 400 gpm (0.17 to 0.89 cfs). One header, constructed full-scale of aluminum pipe, was attached to an existing water supply, tank, and weir box. The purpose of the study was to determine head-discharge relations and jet velocities for 1-1/4- and 1-inch nozzles.
- (f) Tests completed; final report in preparation.
- (g) Pressures, relative to tailwater, in the 8-inch supply pipe 2 feet upstream from a reducing elbow and at the top of the header, and pressures at the top of the header (corrected for the distance between the point of measurement and the pond water surface) can be used as a discharge rating at the hatchery. Flow distribution was uniform with 1-inch nozzles. With 1-1/4-inch nozzles, more flow was discharged at the bottom of the header. The highest exit velocities were at the top edge of all nozzles. The impingement of expanding outflow jets on one another caused them to oscillate horizontally.

(7113)

MODEL STUDY OF HIGH HEAD NAVIGATION LOCK.

- (b) Office, Chief of Engineers.
- (d) Experimental; applied research.
- (e) The 1:25-scale model of the filling and emptying system for Lower Granite lock was modified for tests with lift heights other than that for which the lock was designed (105 feet). See (5071) for description of project. The purpose of the tests was to provide additional information about this new type of hydraulic system (central distribution to eight longitudinal culverts in lock chamber). The proposed work included filling tests with initial heads of 70, 80, and 90 foot, 4- and 8-barge tows, 1 and 2 valves operating, and cushion depths of 15, 17, and 20 feet.
- (f) Suspended.

(7114)

MODEL STUDY OF REVISIONS FOR NORTH FISH LADDER AT JOHN DAY DAM, OREGON AND WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (2662) for description of project. The north fish counting station, with vertical barrier and standard horizontal counting board, is located at the upper end of the sloping ladder just downstream from an 18-pool flow-control and exit section. Flow conditions in a previous model (3578)

were acceptable. However, difficulties with passage of fish (especially shad) in 1968 led to minor revisions of the prototype flow-control section. Continued difficulties in 1969 indicated that major revisions are desirable. It is proposed that the counting station be changed to a vertical-slot type and the flow-control section be modified. A 1:10-scale model includes a portion of the forebay, exit and control sections, counting station, and nine typical pools of the ladder. The purposes of the study are to check proposed revisions and to develop improved designs if required.

- (g) The model was constructed, the vertical-slot counting station was tested, and several alternative designs for revised baffles in the regulatory section were investigated.

(7115)

MODEL STUDY OF NAVIGATION LOCK FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (2662) for description of project. The 86-by 675-foot lock chamber, culvert system, and portions of adjacent approach channels were reproduced in a 1:25-scale model. The purpose of the study was to determine the most advantageous design for the filling and emptying system from the standpoints of rate of operation, degree of turbulence, and economy.
- (f) Tests completed; final report in preparation.
- (g) Undesirable vortex action over the original intakes was eliminated by reversing the left intake so that flow was drawn from the spillway side of the left upstream guide wall. Flow distribution inside the lock chamber was improved by sloping the ports and varying the overhang of roofs for the lateral culverts. The final design lock filled in 11.7 min. and emptied in 13.8 min. under an initial head of 113 feet. Maximum longitudinal forces on an 8-barge tow with a simulated displacement of 11,070 tons were about 5.0 and 2.5 tons during filling and emptying, respectively. Lateral forces were 1.5 tons or less.

(7116)

MODEL STUDY OF SPILLWAY FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (2662) for description of project. A three-bay section of the 20-bay spillway and stilling basin was reproduced to a scale of 1:41,143. In supplemental investigations, two low spillway bays (diversion stage of construction), a section of stilling basin, and portions of adjacent river channel were reproduced in a 1:24-scale model. The purposes of the tests were to check original and modified designs for the spillway and stilling basin.
- (f) Tests completed; final report in preparation.
- (g) Satisfactory designs for the spillway and stilling basin were derived. Pressure data and discharge rating curves were obtained for free and gated flows. Additional tests were made to ensure good conditions for fish at fishway entrances adjacent to the north end of the stilling basin. The low-bay studies indicated that a strong upstream roller would hold rocks and other debris in the stilling basin during second-step diversion. The addition of 7-foot high vertical lips at the downstream ends of the low bays and leaving concrete in the basin below final grade during first-step construction would eliminate danger of scour during the following construction period.

(7117)

MODEL STUDY OF SPILLWAY FOR LIBBY DAM, KOOTENAI RIVER, MONTANA.

- (b) U. S. Army Engr. Dist., Seattle.
- (d) Experimental; for design.
- (e) Libby Dam, at Kootenai River mile 219, will include a spillway with two 48-foot wide bays with crests at elevation 2405, three 10- by 17-foot regulating outlets, and a powerhouse for eight Francis units (ultimate installation 840,000 KW). Three powerhouse units (total capacity 315,000 KW) will be installed initially. At maximum pool elevation 2459, spillway capacity will be 145,000 cfs and total capacity of regulating outlets will be 61,000 cfs. The 116- by 300-foot stilling basin, at elevation 2073, is designed for a maximum spillway discharge of 50,000 cfs. A 1:50-scale model reproduced a portion of the forebay, all hydraulic elements of the spillway and powerhouse, and 1600 feet of exit channel. The purpose of the model was to check the adequacy of the spillway crest, pier, abutments, chute, regulating outlets, stilling basin, and excavated outlet channels.

- (f) Tests completed; final report in preparation.
- (g) The model tests showed that the original spillway abutments, center pier, chute, and stilling basin were not satisfactory. During development tests, the bulkhead slots and upstream projections of pier and abutments were eliminated and the circular abutments were changed to elliptical. The center pier was narrowed from 24 to 20 feet, and both sides of the pier were tapered. A tapered extension of the center pier was used to reduce undesirable rooster tail in flow down the chute. The original stilling basin was 120 feet wide and 172.8 feet long at elevation 2074, and the basin walls were at elevation 2127. The adopted basin is 116 feet wide, 300 feet long, at elevation 2073, and the sidewalls are at elevation 2142. Sizes of rock needed for riprap in exit areas were determined. Six diversion plans were studied before an acceptable plan was selected. Several types of deflectors to prevent debris from lodging against the legs of a contractor's tower were investigated for flows greater than 50,000 cfs during second-stage construction. The adopted plan consisted of two concrete piers 15 feet high and 87 feet long. Each pier acted as a deflector and later would become part of the mass concrete monolith.

(7118)

MODEL STUDY OF OUTLET WORKS FOR LOST CREEK DAM, ROGUE RIVER, OREGON.

- (b) U. S. Army Engr. Dist., Portland.
- (d) Experimental; for design.
- (e) Lost Creek Dam on the Rogue River will provide 315,000 acre-feet of usable storage for flood control and other uses and 49,000 KW of electric power. A multiple-use intake tower with openings at four levels will lead to a 15-foot diameter penstock or to a 12.5-foot diameter regulating outlet. A 6- by 12-foot bypass, for use when the tower is unwatered, will join the penstock. The spillway will include three 45-foot wide bays. Design discharges are as follows: outlet works 9860 cfs at minimum pool elevation 1812, and 11,460 at maximum pool elevation 1872; bypass 2000 cfs; spillway 158,000 cfs. A 1:40-scale model will reproduce a portion of forebay, the multiport intake tower, regulating outlet intake, valve section, conduit and stilling basin, penstock intake and tower bypass, penstock, powerhouse, and a section of downstream channel. A separate 1:40-scale model was used to study flow

conditions and pressures in the bypass and penstock. The purposes of the study are to check flow conditions and pressures in the intake tower, regulating outlet, and penstock, to measure discharges through regulating valves and bypass intake, and to determine performance of stilling basin, tailrace, and downstream channel.

- (f) Design and construction of the bypass model were completed and tests were begun. Design and construction of main model were begun.

(7119)

MODEL STUDY OF FISH LADDER FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (5071) for description of project. The 1:10-scale model included weirs at the upper end of the 20-foot wide, 1-on-10-slope ladder, followed in turn by a 17-foot long diffuser pool, the 1-on-32-slope regulating section with 10 orifice and slot bulkheads on 16-foot centers, the 6-foot wide exit channel, and a section of forebay. The purposes of the investigation were to determine the adequacy of the proposed orifice-slot control section and to develop improvements if required.
- (f) Tests completed; final report in preparation.
- (g) Velocities, flow directions, and head drops were observed for upper pool levels 1 foot below to 1 foot above the normal range of operation. Satisfactory flow conditions and discharge were obtained by reducing orifice dimensions, shortening fins, and using 4-foot high sills in the slots of two bulkheads.

(7120)

MODEL STUDY OF SPILLWAY FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (5071) for description of project. The 1:42.47-scale model included a 3-bay section of the 8-bay spillway, stilling basin, and approach channels. The purposes of the model were to check designs for the spillway crest, piers and abutments, chute, stilling basin, and excavated exit channel, and to develop revisions if required.
- (f) Tests completed; final report in preparation.
- (g) No revisions of the original crest and piers were required. Discharge rating curves for both free and gated flows were obtained. Satisfactory agreement was not obtained between tailwater-jump curves measured in the spillway model and in the general model (study 5071). Return flow into the stilling basin from the powerhouse tailrace and expansion of flow along the lower lock guard wall were responsible for the differences. The adopted design for the stilling basin was based on results of tests in the general model.

(7121)

MODEL STUDY OF NAVIGATION LOCK FOR LOWER GRANITE DAM, SNAKE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental for design.
- (e) See (5071) for description of project. In the unusual hydraulic system, a central junction chamber connects both longitudinal culverts to eight symmetrically-located longitudinal port manifolds (four upstream and four downstream) in the floor of the lock. There are six pairs of ports in each manifold. A 1:25-scale model reproduced a portion of the forebay and floating guide wall, the hydraulic system, the lock chamber, and portions of exit areas and downstream approach. The purposes of the investigation were to check the adequacy of

- the proposed design and to develop modifications if required.
- (f) Tests completed; final report in preparation.
- (g) Turbulence at the water surface and hawser forces on barge tows in the lock chamber of original design were excessive. Pressures downstream from the filling valves at maximum initial head of 105 feet were positive when both valves were opened in 4 minutes, but an instantaneous minimum pressure of -18 feet of water occurred with single-valve operation. Baffles along the walls and over revised manifold ports were developed to reduce turbulence in the lock chamber. Average maximum longitudinal hawser forces on an eight-barge tow were reduced from 6.2 to 1.4 tons and the filling time was decreased from 12.1 to 11.5 minutes for the maximum initial head. Filling time was further decreased to 9.8 minutes and average maximum hawser forces increased to 2.4 tons for an eight-barge tow by using a 1.11-minute valve schedule. Instantaneous minimum pressures downstream from the filling valves were raised from -23 feet to -16 feet for single-valve operation at the faster valve schedule.
- (7122)
MODEL STUDY OF FISH LADDERS FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON.
- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (3577) for description of project. Each of the two fish ladders is 15 feet wide and is constructed with a floor slope of 1 on 10. The partial overflow weirs are 6 feet high, have a 6-foot long baffle or nonoverflow section in the center, and have two 18- by 18-inch orifices at the floor. A 55-pool tangent portion of the proposed fish ladder was reproduced in a 1:10-scale model to obtain discharge data, to check flow stability, flow patterns, and velocities, and to develop revisions if needed.
- (f) Tests completed; final report in preparation.
- (g) Flow patterns within the pools were stable and approximately symmetrical except through the transition from plunging to full shooting flow. This transition will occur at heads and discharges greater than the normal head (12 in.) and discharge (70 cfs). There was no surge action in the model for simulated heads of 3.2 to 18 inches on the weirs.
- (7123)
MODEL STUDY OF NAVIGATION LOCK FOR LOWER MONUMENTAL DAM, SNAKE RIVER, WASHINGTON.
- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) See (3577) for description of project. Except for the intake manifolds, which are staggered in the upstream channel, essential features of the hydraulic system are similar to those previously model-tested and adopted for use at John Day Dam. The 1:25-scale John Day lock model was revised for this study by using the longitudinal culvert intake (John Day elevation 114 = Lower Monumental elevation 396) for elevation control, installing new upstream culvert transitions and intake manifolds, and lowering the approach floor 4 feet for correct depth at intakes. The main purpose of the model study was to obtain acceptable flow conditions (no vortex formation) over the intake manifolds. Pressures in the culvert and hydraulic loads on a proposed revision of the lock emptying valves (skin plate upstream) were measured in the Lower Granite lock model.
- (f) Tests completed; final report in preparation.
- (g) Vortex action occurred over the right intake of original design during a portion of the filling operation. With the adopted intake no vortices formed during any method of operation with steady flow into the lock chamber. Performance of a conventional tainter valve in the emptying culvert was satisfactory. A region of minor negative pressure occurred at the bottom corner of the trunnion support; pressure surges and hydraulic loads on the valve were small.
- (7124)
MODEL STUDY OF PALOUSE RIVER CHANNEL IMPROVEMENT AT COLFAX, WASHINGTON.
- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) The project provides a system of protective levees and improved channels for the main stem and the North and South Forks of Palouse River in Colfax, Washington. Most of the improved channel is concrete-lined and constructed with steep bottom slopes and sharp horizontal curves that will cause supercritical flow, standing waves, and superelevation. The study was made in a 1:40-scale model in a plywood flume that reproduced 6570 feet of the South Fork, 3780 feet of the main stem and North Fork, existing bridges, and proposed elements of the improved channel. The purpose of the study was to check flow conditions with the improvement plan and modify the design if necessary.
- (f) Tests completed; final report in preparation.
- (g) Preliminary tests indicated that enameled surfaces in a 1:40-scale model were too rough to simulate prototype concrete surfaces for which Manning's "n" equals 0.014. Similitude was obtained by using a slope correction factor for model gradients. Test results showed the need for revisions of several transitions and addition of streamlined pier nose extensions to railroad and highway bridges on both Forks. Revisions of invert slope and wall alignment produced satisfactory flow and maintained a hydraulic jump at the design location on the South Fork. A stilling basin and revised channel invert slope were needed to move the jump upstream from two highway bridges. Flow depths in both forks and velocities in riprapped sections downstream from the concrete-lined channels were determined with selected discharges in the project of final design.
- (7125)
MODEL STUDY OF OUTLET WORKS AND TUNNEL FOR RIRIE DAM, WILLOW CREEK, IDAHO.
- (b) U. S. Army Engr. Dist., Walla Walla.
- (d) Experimental; for design.
- (e) Ririe Dam will be a rock-fill structure 184 feet high. Unlined approach and discharge channels will flank a gated spillway in the right abutment. The dam will create a reservoir with about 100,000 acre-feet of storage for flood control and irrigation. The outlet works include an intake tower, control valves, a conduit about 1190 feet long, and a stilling basin. A 1:25-scale model reproduces a portion of the forebay, the intake tower, regulating valves, conduit, stilling basin, and a section of exit channel. The purposes of the study are to check the possibility of vortex formation at the intake, to observe flow conditions, to obtain discharge rating curves, to measure pressures and head losses at critical locations, and to check stilling basin design.
- (g) Flow conditions and pressures in the intake and circular conduit of original design were satisfactory, but the stilling basin was not adequate for the design discharge of 3270 cfs.

(7126)

MODEL STUDY OF SOUTH FORK COEUR D'ALENE RIVER CHANNEL IMPROVEMENT AT WALLACE, IDAHO.

- (b) Idaho State Department of Highways.
- (d) Experimental; for design.
- (e) In the design of Interstate Highway 90, space limitations in the City of Wallace, Idaho, made encroachment of the roadway on the Coeur d'Alene River channel unavoidable. To protect the highway, a paved, high-velocity channel with adequate flood-flow capacity will be constructed through the congested area. Three tributary creeks enter the main stream within the problem reach. A 1:40-scale model reproduced about 7150 feet of channel, of which 6042 feet was to be paved, the creek confluences, and 500 feet of natural channel downstream from the improved section. The purpose of the model study was to verify and refine the proposed design.
- (f) Tests completed; final report forwarded to sponsor.
- (g) The proposed design was adequate in most respects, and some of the proposed modifications were not required. The proposed Corps of Engineers confluence for Placer Creek was satisfactory for all discharges that were reproduced. The size and extent of proposed riprap protection at the downstream end of the channel were more than adequate.

(7127)

MODEL STUDY OF SPILLWAY AND OUTLET WORKS FOR WYNOOCHEE DAM, WYNOOCHEE RIVER, WASHINGTON.

- (b) U. S. Army Engr. Dist., Seattle.
- (d) Experimental; for design.
- (e) The project, located on the Wynoochee River 51.8 miles above its confluence with the Chehalis River, will provide a reservoir with a usable capacity of 59,500 acre-feet of storage for flood control, domestic use, irrigation, and other purposes. The concrete, gravity-type dam will be 175 feet high. A chute spillway, designed to pass 52,500 cfs, will be located in the left abutment. The outlet works include a multilevel intake for two sluices, controlled by 7- by 8.5-foot slide gates, that discharge up to 9000 cfs over an unsubmerged flip bucket into the river channel. A portion of the forebay, the downstream ends of the spillway chute and regulating sluices, the flip bucket, and 720 feet of river canyon downstream from the dam were reproduced in a 1:40-scale model. The purposes of the model study were to develop a satisfactory outlet works, to determine excavation requirements in the downstream channel, to define the tailwater curve, and to check the spillway chute design.
- (f) Tests completed; final report in preparation.
- (g) Performance of the original spillway chute and flip bucket was unsatisfactory. Spillway performance was improved by revising both walls of the chute. The tests indicated that operation of only the right spillway gate should be avoided. An operation plan with greater discharge through the left gate was developed for spillway flows higher than 26,000 cfs. A satisfactory flip bucket, with splitter extended to the end of the bucket, was developed. Proposed excavation in the exit channel was adequate.

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DEPARTMENT OF THE ARMY, WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS, P. O. Box 631, Vicksburg, Mississippi 39181. F. R. Brown, Engineer, Technical Director.

These project summaries are abridged from more detailed descriptions to appear in the Corps of Engineers "Annual Summary of Investigations in Support of the Civil Works Program."

(236)

MISSISSIPPI BASIN MODEL.

- (b) Office, Chief of Engineers.
- (d) Experimental; for design.
- (e) The project provides for construction and operation of a model of the Mississippi River watershed including the Missouri, Ohio, White, Arkansas, and Red Rivers and their principal tributaries. All existing and proposed flood-control reservoirs as well as levees, dikes, floodwalls, and other pertinent works are reproduced. The model area comprises 200 acres, and measures 4500 feet east and west, and 3900 feet north and south. Completed construction consists of the Upper Mississippi River from Hannibal, Mo., to Baton Rouge, La.; the Missouri River from Sioux City, Iowa to the mouth; the Arkansas River from Blackburn Dam site, Okla., to the mouth; the Ohio River from Louisville, Ky., to the mouth; the Cumberland River from Old Hickory Dam, Tenn., to the mouth; the Tennessee River from Pickwick Dam to the mouth; and the Atchafalaya River to the Gulf of Mexico. The topography of the streams and floodplains is being reproduced to a horizontal scale of 1:2000 and vertical scale of 1:100. The purpose is to study the coordination of releases from reservoirs, investigate the effect of reservoir operation on flood stages, check the routing of project and other floods, establish and check levee grades, predict stages, and determine the effect of floodways on stage reduction.
- (g) The extent of model operation each year is determined by the testing programs directed by the Mississippi Basin Model Board and Chief of Engineers and requested by Divisions and Districts that have operable sections on the model. The Comprehensive (basinwide) Testing Program as modified and reduced was completed. These tests for improvement of basinwide reservoir regulation involved evaluation of eight test conditions of reservoir systems and methods of regulation for four historical floods and three hypothetical floods. Use of the model by the Division and District offices has continued.

(425)

DELAWARE RIVER MODEL STUDY.

- (b) U. S. Army Engineer District, Philadelphia.
- (d) Experimental; for design.
- (e) The project provides for a navigation channel about 96 miles long from Trenton, N. J., to Delaware Bay. Included in the project are provisions for constructing dikes and training walls for regulation of tidal flows, and dredging to provide turning basins and adequate anchorage at several points. The purpose is to develop and test plans for reduction of shoaling in several ranges of the navigation channel; and to determine the probable effect on the hydraulic and salinity regimen in the estuary that would result from modifications of channel depth and alignment and flow regulation. The model is of the fixed-bed, silt-injection type with linear-scale ratios of 1:1000 horizontally and 1:100 vertically, and reproduces the entire tidal portion of Delaware River and Bay from the Capes to Trenton, including tidal portions of major tributaries. Tides and tidal

currents are reproduced by automatic tide control mechanisms, and freshwater discharges of the Delaware River and significant tributaries are introduced by means of Van Leer weirs. Observed prototype salinities are reproduced in the Delaware Bay portion of the model, and provisions have been made for the injection of silt into the model, and for measuring silt deposits on the bed of the model. Studies of the dispersion of various contaminants are made by releasing permanent dyes and tracing their movement and concentrations with time after release and distance from the release points.

(f) Suspended.

(993)

CAVITATION RESEARCH.

(b) Office, Chief of Engineers.

(d) Experimental; applied research.

(e) This is a general study, by means of model tests, of the cavitation characteristics of various elements of hydraulic structures, and of the resistance of construction materials to cavitation damage. Further, the investigation includes a review of literature to evaluate the many variables that affect cavitation results.

The purpose is (a) to study cavitation characteristics of such elements as baffle piers, steps in stilling basins, spillway and conduit gate slots, and offset joints. This program will include tests to determine the conditions for dynamic similarity of the cavitation phenomenon; (b) to determine the resistance to cavitation damage of construction materials with particular emphasis on materials suitable for patching concrete. The cavitation characteristics of the various elements are investigated in a variable pressure water tunnel with a 12- by 12-inch test section. Velocities in the test section can be varied from 8 to 35 fps. Resistance-to-damage tests are conducted in apparatus in which cavitation is induced in velocities of 90 fps by an alignment change. Instantaneous pressures are measured on baffle blocks in a 4-foot wide open channel flume.

(g) Pressure measurements on baffle blocks in a 4-foot wide open channel were completed.

(994)

EFFECTS OF MODEL DISTORTION ON HYDRAULIC ELEMENTS.

(b) Office, Chief of Engineers.

(d) Experimental; applied research.

(e) This is a general study of similitude relations in distorted models. The purpose is to determine the hydraulic effects of various types and degrees of model scale distortion on velocity distribution and other hydraulic conditions, with the ultimate aim of establishing limits of permissible distortion for the various types of models. Tests have been conducted in a 5-foot wide masonry flume having a 90-degree bend of 10-foot radius, with a straight approach channel 20 feet long and exit channel 60 feet long, in which can be reproduced a hypothetical stream to a horizontal scale of 1:200 and variable vertical scales to produce distortions up to 1:10. The flume was provided with three venturi meters of different sizes for the control of discharge and a tailgate for the control of tailwater elevation.

(g) Tests to determine the effect of distortion on the results of movable-bed models in the existing 5-foot wide flume were resumed.

(998)

WAVE FORCE ON BREAKWATERS.

(b) Office, Chief of Engineers.

(e) This is a general investigation to (a) study exist-

ing literature and adapt or acquire testing equipment; (b) determine maximum shock-type pressures caused by breaking waves, and delineate the critical conditions necessary to create the extremely high shock pressures; and (c) determine the magnitude of pressures due to partially breaking waves. The purpose is to conduct theoretical and experimental investigations of wave pressures and impact forces on vertical-wall and composite breakwaters from which the magnitude, duration, and location of forces on these structures, caused by breaking waves, can be determined with sufficient accuracy to ensure the design of safe and economical structures.

A 3- by 3- by 6-foot steel tank was used for the experiments on shock pressures caused by the impact of an accelerated plate with a water body. Plastic, aluminum, and steel plates of different masses were dropped into water in the tank and the shock pressures developed were measured and recorded electrically. A 2- by 5.5- by 140-foot concrete wave flume will also be used for conducting experiments on shock pressures and total impact forces caused by waves breaking against vertical-wall breakwaters.

(h) "Water Wave Pressures on Seawalls and Breakwaters," RR 2-10, February 1968.

"An Experimental Study of Breaking Wave Pressures," RR H-68-1, September 1968.

"Shock Pressures Caused by Waves Breaking Against Coastal Structures," RR H-68-2.

(999)

STABILITY OF RUBBLE-MOUND BREAKWATERS.

(b) Office, Chief of Engineers.

(d) Experimental; applied research.

(e) A general study of rubble-mound breakwaters to determine weight, specific weight, and shape of armor units required for stability under wave attack. The purpose of the study is to develop design procedures and formulas, supported by experimental data, from which the design of safe and economical rubble-mound breakwaters can be determined. In addition to quarrystone, the investigation includes tests of tetrapods, tetrahedrons, tribars, quadripods, modified cubes, and other specially molded armor units. Tests are being conducted in a 4- by 4- by 119-foot wave flume.

(h) "Design of Cover Layers for Rubble-Mound Breakwaters Subjected to Nonbreaking Waves; Hydraulic Laboratory Investigation," RR 2-11, June 1968.

"Limiting Heights of Breaking and Nonbreaking Waves on Rubble-Mound Breakwaters; Hydraulic Model Investigation," TR H-68-3, June 1968.

(1002)

EFFECTS OF SCALE AND OPERATING TECHNIQUES ON HARBOR WAVE ACTION AND BREAKWATER MODELS.

(b) Office, Chief of Engineers.

(d) Experimental and theoretical.

(e) A general study is being conducted to determine effects of various model scales and distortion on wave characteristics in harbor and breakwater stability models. The effects on test results of various model-testing techniques are also being investigated. The purpose is to obtain information which will allow more accurate determination of optimum scales for wave models, and the effects of different scales and operating techniques on the accuracy of model results. Screen filter tests were conducted in a 1- by 1.5- by 85-foot steel wave flume in which waves are generated by a hinged-plate type wave generator and are measured and recorded electrically.

(1004)

INSTRUMENTATION.

- (b) Office, Chief of Engineers.
- (d) Experimental; development.
- (e) To develop various types of measurement and control equipment for use in hydraulic models and in the field.
- (g) Development of a water-level indicator for tests of prototype locks was completed. A study to determine the feasibility of using low-range pressure transducers to measure water-surface elevations was continued. Development of a digital recording interval timer was undertaken.

(1467)

DEVELOPMENT OF HYDRAULIC DESIGN CRITERIA.

- (b) Office, Chief of Engineers.
- (d) Analytical; for design.
- (e) The purpose is to analyze hydraulic data, theories, and procedures, to develop design criteria therefrom, and to disseminate this information in the form of Hydraulic Design Criteria to insure adequate capacity, economy of design and construction, and safe and satisfactory operation of the large hydraulic structures being designed, built, and operated by the Corps of Engineers.
- (h) "Hydraulic Design Criteria," 15th issue, 1968.

(1986)

INVESTIGATION OF SALINITY INTRUSION AND RELATED PHENOMENA.

- (b) Office, Chief of Engineers.
- (d) Experimental; applied research.
- (e) The project consists of the following three broad phases: (a) analysis of prototype data to define the range of conditions for which investigations appear desirable; (b) flume tests to study the effects of the various factors involved; and (c) analytical studies aimed at establishment of fundamental laws describing the phenomena involved, and preparation of the data for use in application to specific prototype problems. The purpose of the study is to determine the effects of physical and hydraulic features of estuaries such as tidal prism, tidal range, fresh-water discharge, channel depth, channel width, etc., on the extent of salinity intrusion, the nature of salinity intrusion, the magnitudes and durations of current velocities, and other factors considered essential to proper solution of estuarine problems encountered by the Corps of Engineers.
The flume studies under phase (b) above are being carried out in a transparent flume 327 feet long, 1.5 feet deep, and 0.75 foot wide. One end of the flume is connected to a tidal basin 25 feet square and 5 feet deep, which is equipped with a tide generator capable of producing tides of any desired range, period, or other characteristic. The opposite end of the flume is connected to a circular headbay equipped with weirs for measuring and introducing fresh-water inflows.

(1987)

RIPRAP PROTECTION AT HYDRAULIC STRUCTURES.

- (b) Office, Chief of Engineers.
- (d) Experimental; applied research.
- (e) The erosion characteristics of various sizes of riprap and gravel material are being studied with a view to securing adequate protection at minimum cost. Measurements of velocity and turbulence at which movement of material begins are being made. The purpose is to develop design criteria for riprap at hydraulic structures.

(1988)

WATER TEMPERATURE EFFECTS ON BED FORMS AND ROUGHNESS.

- (b) Office, Chief of Engineers.
- (d) Experimental; applied research.
- (e) It has long been known that water temperature variations caused marked variations in the nature and rate of bed movement, which are of major significance in movable-bed model studies. The onset of cold weather produces excessive riffing of bed surfaces, resulting in sharp increases in roughness values and changes in volumes of material transported. The investigation of this phenomenon is being conducted in existing laboratory flumes, in which water temperatures can be varied to simulate normally experienced summer and winter temperatures. The purpose is to determine the effects of water temperature on stream-bed forms and bed roughness of various types of bed material.
- (g) Testing with coarse sand bed material completed; testing with a medium sand was undertaken.

(2681)

SCALE-EFFECT TESTS OF RUBBLE BREAKWATERS.

- (b) Cooperative with Coastal Engineering Research Center; for Office, Chief of Engineers.
- (d) Experimental; applied research.
- (e) The purpose is to investigate the effects of model scale on the results of experimentally determined criteria for design of rubble-mound breakwaters.
- (f) Completed.
- (g) Stability tests were made of a breakwater slope of 1 on 1-1/2 using wave periods of 2.61, 3.75, 7.87, and 11.33 sec. Tests in the CERC wave flume (15 by 20 by 635 feet) were conducted using a linear scale of 7.5 to 1 based on the tests conducted in the WES 5- by 4- by 119-foot wave flume. Additional stability tests were conducted in the WES 5- by 4- by 119-foot wave flume using linear scales of 0.5 to 1, and 1 to 1, and following the same testing procedure used in the tests conducted in the CERC wave flume. Therefore, data on the stability of rubble-mound breakwaters were available for three different linear scales, 0.5 to 1, 1 to 1, and 7.5 to 1. Test data from the CERC wave flume were correlated with data from the WES flume.

(3906)

GARRISON AND OAHE DAMS, MISSOURI RIVER, NORTH DAKOTA AND SOUTH DAKOTA, POWER-PLANT TRANSIENTS TESTS.

- (b) U. S. Army Engineer District, Omaha.
- (d) Field studies; applied research.
- (e) The purpose is to evaluate results of a comprehensive digital computer study made by the Missouri River Division, Omaha District, and Massachusetts Institute of Technology and to determine extent operation corresponds to design, in order to develop a solution of the entire problem of power-plant transients, with primary emphasis on governing stability. Hydraulic prototype measurements of power-plant transients for different plant loadings, and instantaneous pressure values at a number of locations in the power tunnel, the surge tank system, turbine scroll case, and draft tube were obtained simultaneously with instantaneous values of tunnel flow velocity, reservoir and tailwater elevations, turbine speed and gate opening, power output, and other elements (including governor system). Pressure and water-level measurements were made with electrical pressure transducers, velocities were measured with pressure transducers mounted in probes projecting into the flow and connected to pitot-static tubes on cross struts in the penstock, and mechanical and electrical values were obtained with appro-

- prate transducers. Measurements were recorded on about 90 channels of oscillograph and magnetic tape recorders, and digitized for use in the digital computer analyses by the Omaha District and Massachusetts Institute of Technology.
- (f) Completed.
- (h) "Prototype Measurements of Hydro-Power Plant Transients, Garrison and Oake Dams, Missouri River, North and South Dakota," TR H-68-1. Nov. 1968.
- (3907)
SHOALING PROCESSES.
- (b) Office, Chief of Engineers.
- (d) Experimental; for design.
- (e) The annual cost to the Federal Government of maintaining navigable channels in tidal waterways is estimated to be of the order of \$60,000,000. The Committee on Tidal Hydraulics has concluded that a thorough study of shoaling processes in tidal waterways would lead to improvements in channel design, dredging, and spoiling practices, and other maintenance techniques which would reduce this large expenditure. The Committee concludes that the following program of research is essential in arriving at the objective of reducing maintenance cost: (a) flume studies to determine the basic laws involved in the movement and deposition of muddy sediments; (b) flume studies to determine effects of repetitive scour and deposition on sedimentation; (c) the development of techniques for using radioactive tracers for observing the movement and deposition of sediments in nature; (d) the development of a simple and accurate instrument for in-place measurement of turbidity; (e) a study of the physical, chemical, and hydraulic factors involved in the stabilization of deposits in navigable channels; (f) determination of the effects of flocculation on shoaling; (g) prototype studies aimed at correlation of sedimentation phenomena in tidal waterways with physical, chemical, hydraulic, salinity, and other significant factors; and (h) classification of the sediments which constitute all major repetitive shoals in tidal waterways.
- (h) "A Study of Rheological Properties of Estuarine Sediments," Tech. Bull. No. 7, Committee on Tidal Hydraulics.
- (3912)
GALVESTON BAY (HARBOR), TEXAS, MODEL STUDY.
- (b) U. S. Army Engineer District, Galveston.
- (e) Connecting Galveston Bay and the Gulf of Mexico, is a jettied entrance channel, 36 to 38 feet deep, 800 feet wide, and about 7 miles long. The north and south sides of the channel are protected by rock jetties about 5 and 7 miles long, respectively. Annual shoaling rates are of the order of 600,000 cu. yd. on the inner bar and a like amount on the outer bar. The scour area between the channel and the central portion of the north jetty has deepened from about -30 feet in 1916 to -40 feet or more at the present time, and since old surveys indicate this jetty to be founded in depths of less than -20 feet, there seems to be grave danger that the jetty may be undermined and partially destroyed in the near future. The purpose of this study is to determine: (a) plans for relocation and stabilization of the jetty channel on an alignment and depth suitable for navigation of supertankers; (b) means of protecting the north jetty from undermining action of tidal currents; (c) shoaling characteristics of the relocated and deepened jetty (inner bar) channel and plans for minimizing shoaling; and (d) shoaling characteristics of the deepened outer bar channel. A movable-bed model, with scale ratios of 1:500 horizontally and 1:100 vertically, reproduces about 174.5 square miles of prototype area, including a small portion of Galveston Bay and a portion of the Gulf of Mexico extending 8 miles north of the north jetty, 6-1/2 miles south of the south jetty, and offshore to about the 50-foot contour of depth. Tides, tidal currents, littoral currents, and wave action in the Gulf of Mexico are being reproduced.
- (f) Completed.
- (h) "Model Study of Galveston Harbor Entrance, Texas; Hydraulic Model Investigation," TR H-69-2, Feb. 1969.
- (3917)
GENERAL SPILLWAY MODEL TESTS.
- (b) Office, Chief of Engineers.
- (e) The purpose is to study hydraulic characteristics of spillway crest shapes with heads greater than the design head, including the effects of approach depth, crest piers and gates, elevation of downstream floor of spillway, and of downstream slope of spillway. A flume 70 feet long by 6 feet wide and 6 feet high comprises the test facility. Section models designed for study of particular elements of spillways are installed in the test flume.
- (g) Tests were completed in the investigation of the effects of four different upstream quadrant shapes on discharge coefficients and pressure conditions.
- (4382)
HYDRAULIC PROTOTYPE TESTS.
- (b) Office, Chief of Engineers.
- (e) Assistance is given to Districts in planning and making hydraulic field tests, including: Planning and design of test facilities, making available personnel and equipment for tests, and analyzing data and preparing reports. The purpose is to coordinate the hydraulic prototype testing program of the Corps in order to ensure complete coverage of needed testing, prevent unnecessary duplication of testing facilities and tests, recommend instrument installations at projects where physical and hydraulic conditions will be suitable for obtaining data, and investigate hydraulic performance.
- (g) Assistance in planning prototype instrumentation and tests was furnished to 19 Districts and for 21 projects.
- (4390)
CANNELON LOCKS AND DAM, OHIO RIVER, INDIANA AND KENTUCKY, MODEL STUDIES.
- (b) U. S. Army Engineer District, Louisville.
- (e) The project involves the construction of a non-navigable dam approximately 721 miles below Pittsburgh, Pa., with parallel locks, the main lock to have usable dimensions of 1200 by 110 feet and the auxiliary lock to be 600 by 110 feet. The locks and dams will have a lift of 26 feet, creating a pool up to the McAlpine Locks and Dam at Louisville, Ky. The purpose of the study is to investigate navigation conditions in the lock approaches and effects of the structures on flood stages; to obtain data for development of rating curves; and to determine the effect of powerhouse installation on flow and navigation conditions. A 1:120-scale model reproduces about 9 miles of the river and sufficient overbank areas to permit the reproduction and study of flows up to the maximum of record (1937 flood). The model includes the locks and dam structures with provisions for the installation of powerhouse facilities.
- (f) Suspended.

- (4391)
 LOCK AND DAM NO. 3, ARKANSAS RIVER, ARKANSAS, MODEL STUDY OF NAVIGATION CONDITIONS.
 (b) U. S. Army Engineer District, Little Rock.
 (e) The purpose is to determine the suitability of the proposed site for the lock and dam structure, the effects of proposed regulating works in the vicinity including a cutoff, and modifications which might be required to provide adequate channel depths in the lock approaches and safe navigation conditions with minimum maintenance. A movable-bed model reproducing about 13 miles of the Arkansas River and adjacent overbank area, constructed to a scale of 1:120 horizontally and 1:80 vertically, was used.
 (f) Completed.
 (h) "Navigation Conditions at Lock and Dam No. 3, Arkansas River, Arkansas and Oklahoma; Hydraulic Model Investigation," TR H-68-8, Sept. 1968.

- (4396)
 COLUMBIA RIVER ESTUARY, MODEL STUDY.
 (b) U. S. Army Engineer District, Portland.
 (e) The existing authorized project in Columbia River provides for a channel 48 feet deep and one-half mile wide from the entrance to about river mile 3.0, and thence 40 feet deep and 600 feet wide to Portland, Oreg. The purpose is to determine the need for and to develop optimum plans for rehabilitation of existing jetties and proposed additional improvements; to investigate future shoaling developments in the entrance channel and in the reach between the entrance and Oak Point, and means of alleviating such shoaling; and to investigate existing and proposed spoil-disposal areas to establish locations that will not permit movement of material back to the channel. The model reproduces the lower 52 miles of the Columbia River and pertinent off-shore areas to linear scales of 1:500 horizontally and 1:100 vertically. Tides and tidal currents, density currents, waves, and other phenomena significant to the movement and deposition of sediments are reproduced and studied.
 (h) "Model Studies of Navigation Improvements, Columbia River Estuary; Rept. 1, Hydraulic and Salinity Verification," TR 2-735, Dec. 1968.

- (4602)
 LOCK FILLING AND EMPTYING SYSTEMS.
 (b) Office, Chief of Engineers.
 (d) Analytical and model; applied.
 (e) To provide new or improved design information and procedures to assist in the design of navigation lock filling and emptying systems. Flumes with required appurtenances are available for testing, at scales of 1:25, filling and emptying systems of locks as large as 110 feet by 1200 feet with lifts of 100 feet.
 (g) A longitudinal floor culvert system can be designed to provide excellent performance under a variety of operating conditions. Both the four and eight floor culvert arrangements have practical usage, depending upon the submergence and lift. Some relative effects of various crossover culvert designs and floor culvert arrangements on performance were determined with additional similar testing currently in progress.

- (5228)
 CRITERIA FOR THE DESIGN OF SMALL-BOAT HARBORS.
 See California Institute of Technology (5014).

- (5229)
 GENERAL COASTAL INLET STUDIES.
 (b) Office, Chief of Engineers.
 (c) Experimental; laboratory and field; applied.
 (e) This is a general study to develop means for computing discharge and velocity distribution through tidal inlets, leading to determination of tidal prisms and water-surface elevations in inner bay systems; and to determine the factors involved in both inner and outer bar formation, the shoaling of inlet channels, and the stability of inlet shape and location. The project will consist of the following three phases: (1) tests in four generalized test facilities, three of which (Facilities A, B, and C) will be located at the Waterways Experiment Station and the fourth at the Coastal Engineering Research Center; (2) analysis of results of these tests by the Waterways Experiment Station, the Coastal Engineering Research Center, and the Committee on Tidal Hydraulics; and (3) field observations under sponsorship of the Committee on Tidal Hydraulics to confirm the principles developed.

- (5231)
 OZARK LOCK AND DAM, ARKANSAS RIVER MODEL STUDY OF NAVIGATION CONDITIONS.
 (b) U. S. Army Engineer District, Little Rock.
 (e) The project involves the improvement of the Arkansas River for navigation from the vicinity of Tulsa, Okla., to its junction with the Mississippi River. The 9-foot deep channel will be provided by a system of locks and dams and channel regulating and stabilization works. The channel in the lower reach is to have a minimum width of 250 feet and lock chambers 110 by 600 feet. The purpose of the study is to: (a) demonstrate flow conditions in the lock approaches; (b) measure the distribution of flow across the model at the axis of the dam for a number of flows; and (c) assist in developing modifications of the approaches and structures to improve navigation conditions. The investigation was conducted on a 1:120-scale, fixed-bed, comprehensive model, reproducing about 3 miles of the Arkansas River, adjacent overbank areas to an elevation of approximately 385 feet msl, the lock and dam structures, and all bridges and other structures that might affect flow conditions.
 (h) "Navigation Conditions at Ozark Lock and Dam, Arkansas River; Hydraulic Model Investigation," TR H-68-10, November 1965.

- (5233)
 ST. CLAIR RIVER, MODEL STUDY OF SUBMERGED SILLS.
 (b) U. S. Army Engineer District, Detroit.
 (e) The St. Clair River project, proposed for the head of the St. Clair River, will involve construction of submerged sills in an effort to raise the level of Lake Huron. The purpose of the investigation is (a) to study effects of number and location of submerged sills on discharge characteristics, navigation conditions, and sedimentation; and (b) to investigate effects of shape of weir of discharge characteristics. The comprehensive model reproduced the St. Clair River from Lake Huron to a point about 3.1 miles downstream to a scale of 1:60; this model was of the fixed-bed type with provisions for the study of sediment movement and for the study of shoaling in the critical area.

- (5243)
NOLIN DAM, NOLIN RIVER, KENTUCKY, PROTOTYPE TESTS, GATED INTAKE AND TUNNEL.
- (b) U. S. Army Engineer District, Louisville.
- (c) Nolin Dam is a rock-fill dam, 169 feet in height, used for flood control. The outlet works, consisting of a three-gated intake structure and semielliptical-shaped tunnel, has a 16,000-cfs capacity. An uncontrolled saddle-type spillway is located on the right abutment. The purpose of the study is to measure the tunnel hydraulic grade line and gate-hoist cylinder pressures. From these measurements, tunnel friction and intake losses can be evaluated and gate forces computed. Test facilities included five pairs of sidewall piezometers connected to a manifold. Pressures at full tunnel flow were measured by means of the air-purge technique, using a mercury manometer and a pressure gage. Pressure taps were provided in one of the operating gate-hoist cylinders and measurements of gate hydraulic cylinder pressures were made with pressure gages.
- (f) Suspended.
- (5245)
HOUSTON SHIP CHANNEL, TEXAS, MODEL STUDY.
- (b) U. S. Army Engineer District, Galveston.
- (c) The purpose of the study is to determine if the present cost of maintenance dredging can be reduced by proposed plans of channel realignment, partial or complete diking of connecting bays, sediment traps, dikes in Galveston Bay, local contractions, enlargements, and other remedial measures. The model reproduces a portion of the Gulf of Mexico outside the entrance to Galveston Bay; all of Galveston and Trinity Bays; Dickinson Bay and Clear Creek to the head of project; the tidal portion of Trinity River; the Houston Ship Channel in its entirety; and Buffalo Bayou from the Turning Basin to the confluence of White Oak Bayou. The model is of fixed-bed construction with scale ratios, model to prototype, of 1:600 horizontally and 1:60 vertically. Tides and tidal currents are reproduced by a tide generator located in the Gulf of Mexico portion of the model, and the salinity of the model Gulf is reproduced to scale so that the effects of salinity differences on the vertical distribution of current velocities, as well as salinity concentrations throughout the model, accurately reproduce those of the prototype. The model will be used to establish the effects of all proposed improvement works on tidal current velocities, current patterns, and salinities in all critical areas. All hydraulic and salinity data obtained from the model will be quantitative and can be applied directly to the prototype. Shoaling studies are made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling as observed in the prototype, following which the effects of proposed improvement plans on shoaling patterns may be observed and evaluated from a qualitative viewpoint.
- (g) Results of tests of the barrier (Alpha) designed for the mouth of Galveston Bay indicated that the cross-sectional area of the tidal passages could be reduced about 20 percent without adverse effects on tides, salinities, or dye dispersion patterns in the Galveston Bay area.
- (5246)
UNIONTOWN LOCK AND DAM, OHIO RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.
- (b) U. S. Army Engineer District, Louisville.
- (c) The project involves construction of a dam consisting of a gated section with crest at el 312, a fixed overflow section with crest at el 344, and two parallel locks. The main lock chamber will have clear dimensions of 110 by 1200 feet. The auxiliary lock, 110 by 600 feet, will be located on the right bank. The purpose is to investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangement of the structures, and to develop any modifications considered desirable. The investigation is being conducted on a 1:120 model reproducing about 8.6 miles of the Ohio River and adjacent overbank area near Uniontown, Ky., the lock and dam structures, and the lower reach of the Wabash River.
- (g) Results indicate that satisfactory navigation conditions could be developed with a lock on the river side of the existing locks and that conditions would be better with a gate in between the existing locks and the river-side lock.
- (5251)
ROBERT S. KERR LOCK AND DAM, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.
- (b) U. S. Army Engineer District, Tulsa.
- (c) The Robert S. Kerr Lock and Dam, to be located at about mile 395 on the Arkansas River, will involve construction of a nonnavigable-type dam, a 110-by 600-foot lock, and a powerhouse. The lock will provide a maximum lift of about 48 feet. The purpose of the investigation is to study navigation conditions in the approaches to the lock, determine suitability of the selected site, and develop modifications required to overcome any undesirable conditions. The model reproduced about 3.2 miles of the Arkansas River and the lock and dam structures to a scale of 1:120. It was a fixed-bed model with provision for a movable-bed section below the dam for use in the development of channel configurations in the reach.
- (f) Completed.
- (h) "Navigation Conditions at Robert S. Kerr Lock and Dam, Arkansas River; Hydraulic Model Investigation," TR H-68-5, September 1968.
- (5635)
INVESTIGATION OF WAVE REFLECTING AND TRANSMITTING CHARACTERISTICS OF RUBBLE-MOUND BREAKWATERS, RUBBLE WAVE ABSORBERS, SAND BEACHES, WAVE TRAPS, AND RESONATORS.
- (b) Office, Chief of Engineers.
- (d) Theoretical and experimental; applied.
- (e) A comprehensive study is being conducted to critically review the theoretical aspects of wave absorbers and show their application to practical situations; to develop more accurate methods of measuring wave reflection-absorption characteristics of short-period waves; to investigate the energy transmitted through and over rubble-mound structures; and to determine the wave absorbing characteristics of sand beaches, wave traps, resonators, and certain types of floating breakwaters. The purpose of the study is to establish design criteria (a) for rubble breakwaters with respect to their wave reflecting-transmission characteristics, and (b) for different types of wave absorbers (natural sand beaches, wave traps, resonators, and rubble mound). A 2- by 4.5- by 149-foot concrete wave flume equipped with a flat-type wave generator and electrical wave measuring apparatus was used to conduct tests of the flexible floating breakwater investigation.

- (5638)
LOCK AND DAM NO. 9, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.
- (b) U. S. Army Engineer District, Little Rock.
- (e) The project involves construction of a gated dam and lock. The purpose of the study is to investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangement of the structures and to develop such modifications as might be considered desirable.
- The investigation was conducted on a 1:120-scale model reproducing about 6 miles of the Arkansas River and adjacent overbank area near Morrilton, Ark. The model was of the fixed-bed type with provisions for changes in the channel based on the effects of the proposed regulating structures.
- (f) Completed.
- (h) "Navigation Conditions at Lock and Dam No. 9, Arkansas River; Hydraulic Model Investigation," TR 2-817, March 1968.

- (5639)
LOCK AND DAM NO. 7, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.
- (b) U. S. Army Engineer District, Little Rock.
- (e) The purpose of the investigation is to study navigation conditions in the lock approaches, the design of the upstream guard wall, and location and design of any training works needed to improve navigation conditions and distribution of flow to the spillway. The investigation was conducted on a 1:120 scale, semi-fixed bed, comprehensive model, reproducing about 7 miles of the Arkansas River, adjacent overbank areas, the lock and dam structures, and other structures that might affect flow conditions.
- (f) Completed.
- (h) "Navigation Conditions at Lock and Dam No. 7, Arkansas River; Hydraulic Model Investigation," TR H-69-3, February 1969.

- (5643)
SUMMERSVILLE DAM, ACOUSTIC FLOWMETER INSTALLATION AND PROTOTYPE TESTS.
- (b) U. S. Army Engineer District, Huntington.
- (e) Summersville Dam is a rock-fill dam, 375 feet in height, used for flood control. The outlet works consist of an intake structure, 29-foot diameter operating tunnel, three 11-foot diameter outlet conduits, and one 3-foot diameter low-flow outlet pipe. An uncontrolled, saddle-type spillway is located 3500 feet west of the right abutment. The purpose of the study is to gage operational discharges with an acoustic flowmeter, and to measure pressure gradients through the three-branch manifold connecting the 29-foot tunnel to the three 11-foot conduits; from these measurements, to evaluate tunnel resistance and intake and manifold losses. The acoustic flowmeter included a pair of transducers in the tunnel and each conduit and the accompanying circuitry to indicate the discharge from the effects of the flow rates on the acoustic signals. The pressure test facilities consisted of six pairs of piezometers along the tunnel and three pairs along each conduit.
- (h) "Acoustic Flowmeter Prototype Evaluation Tests," TR 2-810, January 1968.

- (5644)
LITTLE ROCK REACH, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.
- (b) U. S. Army Engineer District, Little Rock.
- (e) The purpose of the study is to study navigation conditions through six bridges at Little Rock,

Ark., to determine modifications required in the existing bridges; and to develop a plan of regulating structures required to provide satisfactory navigation conditions. The investigation is being conducted on a fixed-bed model reproducing about 3 miles of the Arkansas River and adjacent overflow areas to a scale of 1:100, including six railroad and highway bridges.

(g) Results indicate that the shoaling downstream of the bridge could be reduced with regulating structures along the right bank, but some additional modifications would be required for navigation.

- (5647)
GATE VIBRATION TESTS.
- See Iowa Institute of Hydraulic Research (5321).

- (5648)
BRUNSWICK HARBOR, GEORGIA, MODEL STUDY.
- (b) U. S. Army Engineer District, Savannah.
- (e) The purpose of the study is to determine if the present high rate of shoaling in East River can be reduced by either changing the distributions of flows, creating turbulence, increasing bottom velocities, or by reducing the tidal prism of East River to a minimum. The model was of the fixed-bed type molded of concrete to linear scale ratios, model to prototype, of 1:100 vertically and 1:500 horizontally. Automatic tide generators reproduced tides and tidal currents throughout the harbor. Shoaling studies were made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling observed in the prototype, and to determine the effects of proposed improvement plans on shoaling patterns. Changes in shoaling patterns as effected by each proposed improvement plan were determined and evaluated.
- (f) Preparation of final report in progress.

- (5652)
WEBBERS FALLS LOCK AND DAM, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.
- (b) U. S. Army Engineer District, Tulsa.
- (e) The purpose of the investigation is to study navigation conditions in the approaches to the lock, determine the adequacy of the design, and develop modifications required to overcome any undesirable conditions. The fixed-bed model reproduced about 3.1 miles of the Arkansas River and the lock and dam structures to a scale of 1:120.
- (f) Completed.
- (h) "Webbers Falls Lock and Dam, Arkansas River Navigation Project; Hydraulic Model Investigation," TR H-69-11, August 1969.

- (5653)
LAKE ERIE - LAKE ONTARIO WATERWAY MODEL STUDIES.
- (b) U. S. Army Engineer District, Buffalo.
- (e) The project will provide a second navigation passage from Lake Erie to Lake Ontario to supplement the existing Welland Canal. An existing Niagara River model was used to investigate control structure and lock arrangements and navigation channel features including compensating excavations or structures required to maintain existing stage-discharge relations. It may be desirable when the project advances from the survey report stage to the design stage to refine features of the lock plan in an undistorted model. Navigation conditions at the entrance to the overland canal were studied in a second model. The initial phase of the study utilized an existing distorted-scale model which reproduced the Niagara River from approximately 11,500 feet above

the Peace Bridge at Buffalo to Rainbow Bridge below the falls. The upper limit extended into Lake Erie. The model was constructed to scale ratios of 1:360 horizontally and 1:60 vertically, and was of the fixed-bed type with all channel and overbank areas molded in concrete. An undistorted-scale model of a reach of the river at the overland canal entrance was constructed for studying navigation conditions in this area. The model was of the fixed-bed type, constructed to a scale of 1:120.

- (f) Tests complete; report in progress.

(6018)

MONTEREY HARBOR, CALIFORNIA, MODEL STUDY.

- (b) U. S. Army Engineer District, San Francisco.

(e) The purpose of the study is to investigate the arrangement and design of certain proposed harbor improvements with respect to wave and surge action and to determine current conditions in the navigation entrances to the harbor and its basins. The proposed harbor improvements consisted of (a) enlarging the present harbor by construction of a detached north breakwater, approximately 3350 feet in length, and a companion east breakwater connected to shore and extending approximately 1100 feet seaward; and (b) development of the inner-harbor area by constructing moles to form two additional basins for the anchorage of small pleasure craft.

The 1:120-scale model was of the fixed-bed type and was molded of concrete except for the breakwaters which were constructed of rubble, sized to simulate that required for prototype construction. The model reproduced sufficient area along the shoreline northerly, easterly, and oceanward to ensure that propagation of waves shoreward was adequately simulated. The model had an area of 7800 square feet, equivalent to about 4 square miles in nature. Waves were generated by two sections of a vertical-bulkhead plunger-type wave machine which can be aligned so as to reproduce the average curvature of a wave front bent by refraction as it travels through shallow water. The generators, by use of couplings, operated from a single motor power source. Electrical printed-circuit type wave measuring rods were used in connection with automatic recording equipment to obtain necessary wave-height data.

- (f) Completed.

(h) "Wave and Surge Conditions After Proposed Expansion of Monterey Harbor, Monterey, California; Hydraulic Model Investigation," TR-H-68-9, September 1968.

(6019)

FORT SMITH REACH, ARKANSAS RIVER, MODEL STUDY.

- (b) U. S. Army Engineer District, Little Rock.

(e) The purpose of the study is to determine the regulating structures and modifications required to develop a channel of project dimensions, and the modifications required to the existing bridges to provide satisfactory navigation conditions through the reach. The investigation was conducted on an undistorted 1:120-scale, semifixed-bed model, reproducing about 4 miles of the Arkansas River and adjacent overflow areas, the mouth and about the lower 2 miles of the Poteau River, one railroad and one highway bridge, and other structures that might affect flow conditions.

- (f) Completed.

(h) "Navigation Conditions in Fort Smith Reach, Arkansas River; Hydraulic Model Investigation," TR H-68-7, September 1968.

(6020)

LOCK AND DAM NO. 14, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

- (b) U. S. Army Engineer District, Tulsa.

(e) The purpose is to investigate navigation conditions with the proposed structures, to determine the location and width of a navigation channel, and to develop a plan of regulating structures required to provide satisfactory navigation conditions. The investigation is being conducted on a 1:120-scale semifixed-bed model, reproducing about 4.25 miles of the Arkansas River, Bruce Island, Cherokee Chute, and adjacent overbank area near Old Fort Coffee on the right bank and Wilsons Rock on the left bank. The model also includes the lock and dam structure and existing channel regulating structures.

- (g) Final report in progress.

(6021)

LOCK AND DAM NO. 17, VERDIGRIS RIVER, OKLAHOMA, MODEL STUDY OF NAVIGATION CONDITIONS.

- (b) U. S. Army Engineer District, Tulsa.

(e) The purpose is to determine the adequacy of the proposed channel dredging and realignment, and to develop modifications which might be required to overcome undesirable navigation conditions. The investigation was conducted on two 1:120-scale, fixed-bed comprehensive models. One model reproduced about 1.7 miles of the Verdigris River and adjacent overbank area in the vicinity and upstream of Lock and Dam No. 17. The second model reproduced about 2.1 miles of the Verdigris River and adjacent overbank area downstream of Lock and Dam No. 17.

- (f) Tests complete; report in progress.

(6022)

LOCK AND DAM NO. 8, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

- (b) U. S. Army Engineer District, Little Rock.

(e) The purpose is to investigate various plans of regulating structures and to develop modifications as required for the development of a channel of adequate dimensions and satisfactory navigation conditions in the approaches to the lock. The investigation is being conducted on a movable-bed model reproducing about 10 miles of the Arkansas River and adjacent overbank areas to a scale of 1:120 horizontally and 1:80 vertically.

- (f) Final report is in progress.

(6024)

JONES BLUFF LOCK AND DAM, ALABAMA RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

- (b) U. S. Army Engineer District, Mobile.

(e) The project involves the construction of a dam, a 68,000-kw power plant, and a 45-foot lift, 84- by 600-foot lock 245.4 miles above the mouth of the Alabama River. The project will provide 9-foot navigable depths for 80 miles upstream. The purpose of the study is to investigate conditions with the proposed plan and to develop modifications which might be required to overcome any undesirable navigation conditions.

The investigation was conducted on a 1:100-scale, fixed-bed comprehensive model that reproduced the proposed structures and about 3.6 miles of the Alabama River and adjacent overbank area.

- (f) Completed.

(h) "Jones Bluff Lock and Dam, Alabama River Navigation Project; Hydraulic Model Investigation," TR H-69-17, December 1969.

(6025)

TEXAS COAST HURRICANE SURGE MODEL STUDIES.

- (b) U. S. Army Engineer District, Galveston.
- (c) The purpose is to determine the effectiveness of hurricane surge protection plans for the Galveston Bay complex.
The Galveston Bay hurricane surge model reproduces the coast from Freeport on the south to High Island on Bolivar Peninsula on the east. The model includes an average width of the Gulf of Mexico of about 25 miles, measured normal to the Gulf; all of the barrier islands in the bay interior, including its many connecting arms, lakes, and lagoons; and the coastal area within this sector up to a maximum elevation of 20 feet msl. The model reproduces normal tides as well as Gulf surges created by hurricane forces. The model is of the fixed-bed type molded of concrete to linear scale ratios, model to prototype, of 1:100 vertically and 1:3000 horizontally. Automatic tide generators reproduce normal tides and tidal currents throughout the model. The hurricane surges will be reproduced by a horizontal-displacement type surge generator.
- (h) "Galveston Bay Hurricane Surge Study; Report 1, Effect of Proposed Barriers on Hurricane Surge Heights; Hydraulic Model Investigation," September 1969.

(6026)

UMPPKA RIVER ESTUARY, OREGON, MODEL STUDY.

- (b) U. S. Army Engineer District, Portland.
- (c) The existing authorized project in the Umpqua River entrance provides for a channel 26 feet deep at mllw with no specified width for about 5000 feet across the entrance bar, and thence 22 feet deep and 200 feet wide to Gardiner and Reedsport. The purpose of the study is (a) to obtain the optimum layout of a jetty system or other structure to reduce crosscurrent action and maintenance dredging of the entrance to a minimum, and (b) with the optimum for a guide, to adapt the existing jetty system to approach the optimum to the limit allowed by economic considerations. The model reproduces the lower 14 miles of the Umpqua River and pertinent offshore areas to linear scales of 1:300 horizontally and 1:100 vertically. An additional 14 miles of the Umpqua River and 20 miles of the Smith River are reproduced schematically in order to include the upstream tidal reaches. All portions of the model are initially of the fixed-bed type, with provisions for converting the entrance area to a movable-bed type if movable-bed studies are required. Tides and tidal currents, freshwater inflow, density currents, waves, and other phenomena significant to the movement and deposition of sediments are reproduced and studied.
- (f) Report in progress.

(6027)

GASTINEAU CHANNEL, ALASKA, MODEL STUDY.

- (b) U. S. Army Engineer District, Alaska.
- (c) The existing authorized project in Gastineau Channel provides for a channel 75 feet wide with a depth of 0.0 mllw from Fritz Cove to naturally deep water near Juneau, Alaska. The navigation channel is flanked by continuous tidal flats having elevations as much as 15 feet above the channel bottom for a distance of about 3 miles. The purpose of the study is to reduce shoaling in order to maintain a suitable navigation channel; various dike layouts which will isolate the channel cut from the surrounding area will be investigated. The model reproduces the westernmost 8 miles of

Gastineau Channel and Fritz Cove to linear scales of 1:500 horizontally and 1:100 vertically. Tides, tidal currents, and freshwater inflow significant to the movement and deposition of sediments are reproduced and studied. All portions of the model are of the fixed-bed type.

- (g) It was determined that a 17,250-foot long impermeable dike located immediately north of the navigation channel and diversion of Fish Creek away from the navigation channel will reduce channel shoaling by about 90 percent.

(6028)

FIRE ISLAND INLET, LONG ISLAND, NEW YORK, MODEL STUDY.

- (b) U. S. Army Engineer District, New York.
- (c) Fire Island Inlet, located on the south shore of Long Island, N. Y., connects the Atlantic Ocean with Great South Bay. Attempts have been made to stabilize an entrance channel through Fire Island Inlet with little success. The purpose of the study is to: (a) investigate the proposed design of a combination sand bypassing and channel maintenance procedure, consisting of a littoral trap, a rehandling basin, and entrance channel connecting the two, and a training dike; (b) investigate changes in the dimensions and depths of the channel, trap, basin, and dikes through model study; (c) determine the need for extending the Federal Jetty; (d) determine the need for additional dikes; and (e) determine locations and dimensions of any other additional improvement works needed to increase the effectiveness of the plan and maintain a stable channel through the inlet. A fixed-bed model that was later converted to a movable-bed model, with scales of 1:500 horizontally and 1:100 vertically, reproduced all of Fire Island Inlet and a portion of the Atlantic Ocean. Tides, tidal currents, and wave action in the Atlantic Ocean were reproduced.
- (f) Completed.
- (h) "Channel Improvement, Fire Island Inlet, New York; Hydraulic Model Investigation," TR H-69-16, November, 1969.

(6030)

WEST POINT DAM, CHATTAHOOCHEE RIVER, GEORGIA, GENERAL MODEL STUDY.

- (b) U. S. Army Engineer District, Savannah.
- (c) The purpose of the study is to determine the performance of the structure as affected by flow conditions in the approach channel and the development of a satisfactory energy dissipator below the spillway. Particular emphasis was placed on the selection of a basin which would operate satisfactorily under conditions of a high unit discharge and with tailwater depths insufficient for ideal performance of either a roller-bucket or hydraulic-jump type basin. The model tests were conducted on a 1:60-scale general model that reproduced about 1700 feet of the approach, the spillway, powerhouse, and 1500 feet of the exit area. Sufficient overbank areas on each side of the structure were provided to reproduce expected flow conditions. Initial study of the energy dissipator was conducted on a 1:60-scale section model of the spillway and stilling basin which was installed in a 1-foot wide glass-sided flume. This permitted observation of sub-surface flow conditions in the basin and facilitated modifications of the basin.
- (f) Completed.
- (h) "Spillway for West Point Dam, Chattahoochee River, Alabama and Georgia; Hydraulic Model Investigation," TR 2-815, March 1969.

(6032)

OLD RIVER CONTROL STRUCTURE, LOUISIANA, PROTOTYPE TESTS.

(b) U. S. Army Engineer District, New Orleans.

(d) Field study; applied research.

(e) The project, located on the Mississippi River approximately 50 miles downstream from Vidalia, La., consists of an 11-bay, 484-foot long gated spillway. Flood control is obtained by diverting through the structure approximately one-fourth of the flow in the Mississippi River. The purpose of the study is to measure vibration of the structure during periods of high discharge and determine the magnitude of the resulting displacements. Utilizing these data, stresses caused by the dynamic response of the structure will then be computed. Accelerometers to measure vibration in the principal directions were located on the piers, gate guides, and crane rail of bays 6 and 10 as well as the left downstream wing wall and the bridge walkway. Data were recorded on both magnetic tape and oscillograms.

(f) Suspended.

(6033)

KAYSINGER BLUFF DAM, OSAGE RIVER, MISSOURI, GENERAL MODEL STUDY.

(b) U. S. Army Engineer District, Kansas City.

(e) Plans call for an earth-fill dam about 5000 feet long with a height of 96 feet above the valley floor, a 4-bay gated overfall, a hydraulic jump-type stilling basin and an adjacent power facility in the right terrace. The purpose of the investigation is to study the adequacy of the spillway and the performance of the hydraulic jump-type stilling basin with and without diversion through the powerhouse, flow conditions in the outlet channel, and adequacy of various sizes of riprap in the outlet channel.

A 1:60-scale undistorted model that reproduced 1400 feet of the approach and 1900 feet of the exit areas, the spillway, powerhouse, nonoverflow sections, and portions of the earth embankment was utilized to conduct the study.

(f) Completed.

(h) "Spillway for Kaysinger Bluff Dam, Osage River, Missouri; Hydraulic Model Investigation," TR 2-809, January 1968.

(6035)

BARREN RIVER DAM, BARREN RIVER, KENTUCKY, STILLING BASIN PROTOTYPE PRESSURE TESTS.

(b) U. S. Army Engineer District, Louisville.

(d) Field study; applied research.

(e) Barren River Dam is a 146-foot high earth dam used for flood control, recreation, and low flow augmentation. The outlet works are a three-gated intake structure and a 17-foot, elliptically shaped tunnel with a 10,000-cfs capacity. An uncontrolled, saddle-type spillway is located on the right abutment. The stilling basin is 40 feet wide with a single row of streamlined baffle blocks and an end sill.

The purpose of the study is to measure average and fluctuating pressures against the stilling basin side wall and on a baffle block. The side-wall pressure magnitude and areal extent will give useful data for the design of similar stilling basins. Baffle pressures will provide full-scale data on turbulence pressure fluctuations and possible cavitation. Prototype test facilities include four slots for pressure transducer carriages and ten embedded pressure transducer boxes on and near a baffle block. A pressure transducer will be installed on each carriage and measurements made at various flow depths.

Data will be recorded on oscillographs and magnetic tape for later electronic correlation.

(6041)

CRESCENT CITY, CALIFORNIA, MODEL STUDY OF HARBOR.

(b) U. S. Army Engineer District, San Francisco.

(e) The purpose of the study is to determine the optimum length and location of an extension to the existing breakwater system that would reduce to a tolerable level the present adverse influence of storm waves on navigation and mooring conditions in the harbor.

The 1:125-scale model was of the fixed-bed type, and was molded of concrete except for the breakwaters which were constructed of rubble, sized to simulate that required for prototype construction. The model reproduced sufficient area along the shoreline north, south, and oceanward of the harbor site to ensure that propagation of waves toward the problem area was adequately simulated. The model had an area of about 7800 square feet, equivalent to about 4.4 square miles in nature. Waves were generated by a 60-foot long, plunger-type wave machine.

(f) Completed.

(h) "Design for Optimum Wave Conditions, Crescent City Harbor, Crescent City, California; Hydraulic Model Investigation," TR H-68-6, September 1968.

(6042)

INVESTIGATION OF PROPOSED DIKE SYSTEMS (FORMERLY LABORATORY RESEARCH ON DIKE DESIGN).

(b) Memphis, Vicksburg, and New Orleans Districts.

(e) The project involves the construction of dikes for the regulation and improvement of alluvial streams, such as the Mississippi River, to provide for adequate channel depth and alignment for navigation. The purpose of the study is to determine the effectiveness of proposed dike plans in stabilizing low-water channels and in providing the required increase in depth. The investigation is being conducted in a flume 150 feet long with a width varying from 30 to 90 feet. The study is of the movable-bed type with a fine, uniform sand used for bed material.

(6038)

BELTZVILLE DAM, POHOPOCO CREEK, PENNSYLVANIA, MODEL STUDY OF OUTLET WORKS.

(b) U. S. Army Engineer District, Philadelphia.

(e) The outlet works consist of an inlet channel, a controlled-type intake tower, a rectangular conduit, stilling basin, and an outlet channel. The purpose of the study is to investigate the hydraulic characteristics and develop the optimum design of a selective withdrawal outlet works. A 1:20-scale model is being used in the study. The model reproduces a sufficient area of the reservoir to obtain natural conditions at the intake, the intake structure and conduit, the stilling basin, and about 100 feet of the outlet channel. Fresh and salt waters are being used to simulate anticipated conditions of stratification in the reservoir and evaluate the effectiveness of the proposed structure to selectively withdraw from the desired levels of the reservoir.

(f) Completed.

(h) "Outlet Works for Beltzville Dam, Pohopoco Creek, Pennsylvania; Hydraulic Model Investigation," TR H-68-18, December 1969.

(6840)

COPAN DAM, LITTLE CANEY RIVER, OKLAHOMA, MODEL STUDY.

(b) U. S. Army Engineer District, Tulsa.

(e) The spillway will be on the right abutment of the dam and will contain four 50- by 35.5-foot tainter

gates. The weir crest will be at elevation 696.5. The stilling basin will consist of a 132.5-foot horizontal apron at elevation 665.5. The purpose of the study is to investigate stilling basin performance, exit flow conditions, flow conditions over the retaining dike, and the stability of riprap on the dike and dam embankments.

The investigation is being conducted on a 1:60-scale model that reproduces the spillway, 1600 feet of the exit area, and sufficient overbank area on each side of the structure.

- (f) Tests complete. Report in progress.

(6841)

HUGO DAM, KIAMICHI RIVER, OKLAHOMA, MODEL STUDY OF SPILLWAY.

- (b) U. S. Army Engineer District, Tulsa.

(e) The project will include a gated spillway with a gross crest length of 290 feet at an elevation of 387.5. Earth embankments with tops at elevation 452.5 extend to high ground on each side of the structure. The structure will provide flood control and more dependable streamflow. The purpose of the study is to investigate approach flow conditions, exit flow conditions, optimum elevation of the stilling basin apron, discharge characteristics of the structure, and flow conditions in the vicinity of two bridges located downstream of the structure. The investigation was conducted on a 1:60-scale general model that reproduced 1600 feet of the approach, the spillway, 1600 feet of the exit area, and sufficient overbank area on each side of the structure.

- (f) Completed.

(h) "Spillway for Hugo Dam, Kiamichi River, Oklahoma; Hydraulic Model Investigation," TR H-69-15, November 1969.

(6842)

KAW DAM AND RESERVOIR, ARKANSAS RIVER, OKLAHOMA MODEL STUDY OF SPILLWAY.

- (b) U. S. Army Engineer District, Tulsa.

(e) The ogee spillway (crest elevation of 997.5) consists of eight 50-foot wide by 47-foot high tainter gates. The purpose of the study is to investigate approach and exit flow conditions, discharge characteristics of the structure, and wave heights in the vicinity of the downstream embankments. The investigation is being conducted on a 1:100-scale general model that reproduces 3000 feet of the approach, the spillway, 2500 feet of the exit, and sufficient overbank area on each side of the structure.

(g) A dike extending downstream from the left embankment and parallel to the left training wall reduced the scour hole downstream from the basin. A dike was considered more economical than increasing the size of the left training wall.

(6843)

MERAMEC PARK RESERVOIR, MERAMEC RIVER, MISSOURI, MODEL STUDY OF OUTLET WORKS.

- (b) U. S. Army Engineer District, St. Louis.

(e) The project provides a vertical-faced weir upstream of the proposed gated intake structure for control of the temperature of water discharged downstream. Releases will pass over the weir and through the intake structure and 14-foot diameter, concrete-lined tunnel into a conventional stilling basin and the exit channel. The purpose of the investigation is to evaluate the effectiveness of the proposed water temperature control weir to selectively withdraw surface and near-surface waters from a stratified reservoir. A 1:40-scale model is being used to reproduce an 800-foot long by 500-foot wide portion of the

reservoir, the approach channel, weir, and the intake structure.

- (g) The weir was found to be effective for containing the cold water during release of desired rates of flow of 131 to 1028 cfs from the water supply and water-quality control (joint use) pool (elevation 608.0 to 675.0). Some withdrawal of cold water (approximately 7 percent) was observed with a discharge of 8000 cfs and a pool elevation of 680.0. The results of this study and the results of the Clarence Cannon and West Point water temperature control weirs were used to develop a preliminary, generalized technique for predicting the effectiveness of submerged weirs.

(6844)

NEW HOPE DAM, CAPE FEAR RIVER BASIN, NORTH CAROLINA, MODEL STUDY OF OUTLET WORKS.

- (b) U. S. Army Engineer District, Savannah.

(e) The structure will be constructed across the Haw River immediately below the mouth of the New Hope River and will include a multilevel intake structure and the adjoining outlet works consisting of a 19-foot diameter conduit approximately 330 feet long and a conventional hydraulic-jump type stilling basin. The purpose of the investigation is to determine the hydraulic characteristics of the proposed intake structure and outlet works including pressure conditions, discharge capacity, flow conditions, and stilling basin performance. Flow conditions through and discharge capacities of the multilevel intakes are of particular interest since they are related to water quality interests.

A 1:20-scale model that reproduced a 200-foot wide, 300-foot long portion of the reservoir, the intake structure and conduit, the stilling basin and a 350-foot wide, 500-foot long section of the exit channel was used for conduct of the study.

- (f) Completed.

(h) "Outlet Works for New Hope Reservoir, Cape Fear River Basin, North Carolina; Hydraulic Model Investigation," TR H-69-14, October 1969.

(6845)

REND LAKE RESERVOIR, BIG MUDDY RIVER, ILLINOIS, MODEL STUDY OF SPILLWAY.

- (b) U. S. Army Engineer District, St. Louis.

(e) The project provides for a flood-control reservoir on the Big Muddy River approximately 50 miles north of Cairo, Ill., and will include an uncontrolled spillway with a gross crest length of 435 feet at elevation 410 msl. Initial plans provided a 25-foot wide notch with crest elevation of 405 in the center of the structure for the purpose of releasing flows up to 1000 cfs, the bank-full capacity of the downstream channel. The purpose of investigation is to study the adequacy of the spillway, stilling basin, and exit channel protective stone.

Model tests were conducted with a 1:16-scale section model that reproduced 120 feet of the spillway (approximately 30 percent of the total) including the notched section and two adjacent 52-foot wide portions of the spillway with crest elevation of 410. Approach and exit channels were reproduced for distances of 250 and 300 feet, respectively. Upon completion of tests of the notched portion of the spillway, the model was revised to investigate flow conditions in the vicinity of the right abutment.

- (f) Completed.

(h) "Spillway for Rend Lake Reservoir, Big Muddy River, Illinois; Hydraulic Model Investigation," TR H-69-7, May 1969.

(6846)

STUDIES OF SELECTIVE WITHDRAWAL FROM STRATIFIED RESERVOIRS.

- (b) U. S. Army Engineer Districts, Savannah and Philadelphia.
- (d) Experiment and analytical; applied.
- (e) Research initiated to assist in the design of multilevel intake structures for the purpose of selectively withdrawing quality water from various levels of a stratified reservoir. The purpose is to determine the effect of the size and shape of an orifice on selective withdrawal characteristics from a stratified reservoir and to determine the limits of the zone of withdrawal, which will aid in locating monitoring systems. The model facilities consisted of a 1-foot wide by 2-foot deep by 24-foot long transparent plastic flume connected to a 15-foot wide by 42.5-foot long forebay. Fresh water and salt water were used to simulate a two-layer stratification of a given density differential. An orifice located in a removable plastic plate was installed across the flume. The flow through the orifice was regulated by setting up various head differentials across the plate. A digital thermometer and several thermistors were used for measurement of temperatures throughout the system and a conductivity probe was used for determining the salinity profile. Density profiles were determined by combination of the effects of temperature and dissolved salt concentrations. Velocity distributions were determined by photographing the displacement of dye streaks with time.
- (f) Completed.
- (h) "Mechanics of Flow from Stratified Reservoirs in the Interest of Water Quality; Hydraulic Laboratory Investigation," TR H-69-10, July 1967.

(6847)

TOKCS ISLAND DAM, DELAWARE RIVER, PENNSYLVANIA, GENERAL MODEL STUDY.

- (b) U. S. Army Engineer District, Philadelphia.
- (e) The project calls for a chute spillway (gated) in the left abutment to return high flows released from the reservoir to the river approximately 1050 feet downstream of the dam axis. An intake structure and powerhouse together with outlet works are included in the same general area. Discharges from the outlet works will reenter the river downstream of dam through a separate stilling basin. The purpose of the study is to verify the performance of the structure with emphasis on approach conditions to the spillway, stilling basin performance as affected by outlet works releases, and the location of the outlet works stilling basin. Two models are being used in the study: (a) a 1:60-scale general model reproduces the entire spillway and outlet works and about 2200 feet of approach and 3000 feet of the exit area. Sufficient overbank area is reproduced to simulate expected flow conditions; (b) a 1:64-scale spillway model was used to determine the possibility of combining energy dissipation features of the spillway and outlet works.
- (f) Final report in progress.

(6848)

TIDES AND CURRENTS IN TIDAL WATERWAYS.

See also (6414), Massachusetts Institute of Technology.

- (b) Office, Chief of Engineers.
- (d) Analytical; applied.
- (e) The project involves evaluating of the various methods used or proposed for computation of tides and currents in estuaries and tidal canals. The study will be carried out in three phases: (a) a

quantitative analysis of the effect of various approximations used in the "Brown's Reflected Wave Theory" and "Pillsbury's Slope Method," the two existing methods in common use for the prediction of vertical rise and fall of the tide and tidal flow patterns, to ascertain which (if either) of the various approximations may best be applied in any specific problem, and to pave the way, if possible, to other methods of calculation that would eliminate any shortcomings that may be revealed in the existing calculation methods; (b) check of the calculations of the first phase with data determined from existing tidal estuaries and/or canals, and from experiments conducted in laboratory models or other apparatus; work under this phase will include recommendation for the aforementioned laboratory investigation, close liaison therewith, and full use of data derived therefrom; (c) final development of a method of calculating tides and tidal currents in canals and estuaries. The purpose is to develop an accurate method for computing tides and currents in estuaries and tidal canals.

- (h) "The Computation of Tides and Currents in Estuaries and Canals," D. R. F. Harleman and C. H. Lee, Tidal Hydraulics Ship Committee Tech. Bull. No. 16, September 1969.

(6849)

CHESAPEAKE BAY, MODEL STUDY.

- (b) U. S. Army Engineer District, Baltimore.
- (e) The purpose is to provide assistance in developing plans to improve the hydraulic, salinity, pollution, shoaling, and hurricane tide conditions that exist in the Chesapeake Bay Basin. The model will be of the fixed-bed, silt-injection type with linear scale ratios of 1:1000 horizontally and 1:100 vertically, and will reproduce a portion of the Atlantic Ocean, all of Chesapeake Bay and the tributaries up to the limit of tidal action. The model will reproduce adjacent overbank areas up to the \pm 20-foot msl contour. Tides and tidal currents will be reproduced in the model by automatic tide control machines and the appropriate freshwater inflow will be introduced into all major tributaries entering the bay. Observed prototype salinities will be produced in the ocean and by portion of the model, and provisions will be made for injecting silt into the model to simulate shoal deposits in the prototype. Studies of the dispersion of various contaminants will be made by releasing permanent dyes and tracing the movement of concentration with respect to time after release of the dye.
- (f) Suspended.

(6850)

HOUSTON SHIP CHANNEL, RADIOACTIVE SEDIMENT TRACER TESTS.

(See also (5245).)

- (b) U. S. Army Engineer District, Galveston.
- (c) Field study; applied research.
- (e) The purpose is to trace the movement of radioactive sediment in order to determine how shoals are formed in the prototype so that the model can be adjusted, if necessary, to react in a similar fashion. Various pieces of equipment were used for activating, placing in the channel, and tracing the sediment. The isotope gold 198 was utilized in the activation phase. The isotope was mixed with sample sediment in a special tank from which it was removed and placed on the channel floor by water pressure. A scintillation detector was attached to a sled pulled along the bottom for measuring activity. The activity was received

and recorded by electronic equipment on the test boat.

- (f) Completed.
- (h) "Radioactive Sediment Tracer Tests, Houston Ship Channel, Houston, Texas," MP H-69-2, Mar. 1969.

(6852)

SAN DIEGO BAY, CALIFORNIA, MODEL STUDY.

- (b) U. S. Army Engineer District, Los Angeles.
- (e) The proposed second entrance is needed to alleviate navigational hazards and delays, harbor congestion, and pollution problems. The purpose is to determine the effects of a second entrance to the bay across the southern portion of Silver Strand on the hydraulic regimen, circulation, pollution, and shoaling patterns of the Bay and adjacent areas.
- The San Diego Bay model is of the fixed-bed type with a vertical scale of 1 foot (model) to 100 feet (nature) and a horizontal scale of 1 foot (model) to 500 feet (nature). The area covered by the model extends from just north of Point Loma to just south of the southern extremity of the bay and oceanward to the 100-foot contour of depth, representing approximately 108 square miles of prototype area. The model itself covers an area of about 12,000 square feet. The model reproduces to scale all the hydraulic factors present in nature, such as tidal heights, current velocities, and circulation patterns.
- (g) It was determined that the flushing rate for the bay was significantly improved with either of the second openings tested. Detailed analysis of the dispersion and flushing tests will be accomplished by the Navy.

(6854)

DARDANELLE LOCK, ARKANSAS RIVER, ARKANSAS, MODEL STUDY OF FILLING AND EMPTYING SYSTEM.

- (b) U. S. Army Engineer District, Little Rock.
- (e) The filling and emptying system for the lock will comprise two intake manifolds, a 14.5-foot wide by 13-foot high culvert in each wall, a lateral crossover culvert at the midpoint of the lock leading to four longitudinal culverts with side ports, and culvert outlets which empty riverward of the lock in the common outlet basin. Reverse-mounted culvert valves will control flow in the system. The purpose of the study is to investigate the suitability of a longitudinal floor culvert system for filling and emptying the lock under heads and submergences which will obtain at Dardanelle Lock site.
- A 1:36-scale test facility was used to develop the crossover culvert entrance. A 1:25-scale general model reproducing the 670- by 110-foot lock chamber, the culvert system, and outlets was used to study filling and emptying.
- (f) Completed.
- (h) "Filling and Emptying System, Dardanelle Lock, Arkansas River; Hydraulic Model Investigation," TR H-69-5, April 1969.

(6855)

KASKASKIA RIVER ILLINOIS, NAVIGATION PROJECT MODEL STUDY.

- (b) U. S. Army Engineer District, St. Louis.
- (e) The project provides for 50 miles of channel enlargement and realignment from Fayetteville, Ill., to mouth; alterations to bridges to obtain proper clearance; and construction of a low, gated dam surmounted by two 60-foot wide by 30-foot high tainter gates, and a 600-foot long by 84-foot wide navigation lock located at mile 0.8. The purpose of the study is to demonstrate and study flow conditions in the lock approaches and in

critical reaches reproduced in the model; determine adequacy of the proposed design for the spillway, stilling basin, and exit channel; determine the optimum arrangement of the guide or guard walls; determine areas requiring special protection and navigation conditions in the lock approaches and in critical reaches, and develop modifications required to produce satisfactory flow and navigation conditions.

The investigation was conducted on a 1:120-scale, fixed-bed, comprehensive model, reproducing 2 miles of the Kaskaskia River and adjacent overbank to the levee on the right side and to the railroad embankment on the left side, 1.8 miles of the main Mississippi River channel, and the lock and dam structures.

- (f) Completed.
- (h) "Kaskaskia River Navigation Project, Illinois; Hydraulic Model Investigation," TR H-69-1, January 1969.

(6856)

LOCK AND DAM NO. 13, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

- (b) U. S. Army Engineer District, Little Rock.
- (e) The purpose of the investigation is to study navigation conditions in the lock approaches, determine the effects of existing and proposed channel rectification works and additional works that may seem desirable to produce satisfactory navigation conditions, and determine effects of a proposed bridge crossing at the lock and dam.
- The investigation was conducted on a 1:120-scale, semifixed-bed, comprehensive model, reproducing about 7 miles of the Arkansas River, adjacent overbank areas, the lock and dam structures, and other structures that might affect flow conditions.
- (f) Final report in progress.

(6857)

LOCKS AND DAM NO. 26, MISSISSIPPI RIVER, MODEL STUDY.

- (b) U. S. Army Engineer District, St. Louis.
- (e) The purpose of the study is to determine the arrangement of the locks at the existing site and at a new location about 2 miles downstream, which would provide the best navigation conditions in the upper and lower lock approaches. The investigation is being conducted on a 1:120-scale, fixed-bed, comprehensive model, reproducing about 6.8 miles of the Mississippi River, adjacent overbank areas, the locks and dam structures, a railroad and highway bridge, and other structures that might affect flow conditions.

(6858)

NEWBURGH LOCK, OHIO RIVER, MODEL STUDY OF FILLING AND EMPTYING SYSTEM.

- (b) U. S. Army Engineer District, Louisville.
- (e) The purpose of the study is to investigate the effect of the relative position of the filling valves and port manifold on lock filling characteristics in a sidewall port system for a 110- by 1200-foot lock.
- A 1:25-scale model which reproduced only the portion of the main Newburgh Lock between filling and emptying valves is adequate for the purpose of the model investigation. The 1270- by 110-foot lock was reproduced. The model includes 14-foot wide by 16-foot high culverts, sidewall port manifold, and reverse-mounted culvert valve to control flow. Other features of the system remained as they were in an earlier study.
- (f) Completed.
- (h) "Effect of Valve Position in a Sidewall Port Filling System, Newburgh Lock, Ohio River;

(6859)

SMITHLAND LOCKS AND DAM, OHIO RIVER, GENERAL MODEL STUDY.

- (b) U. S. Army Engineer District, Nashville.
- (e) The purpose of the study is to determine the optimum location and alignment of the locks and dam; to investigate shoaling and erosion tendencies; and to develop modifications which might be required to overcome any undesirable conditions. A 1:150-scale comprehensive model, which can be converted from fixed- to movable-bed, reproduces the proposed structures and about 8.5 miles of the Ohio River and adjacent overbank area to the bluff lines. The model also reproduces a short reach of the Cumberland River above its junction with the Ohio River.

(6860)

ANSONIA-DERBY LOCAL PROTECTION PROJECT, HOUSATONIC AND NAUGATUCK RIVERS, CONNECTICUT, MODEL STUDY.

- (b) U. S. Army Engineers, New England Division.
- (e) The project will provide flood protection to properties on both sides of the rivers in the event of the standard project flood. The purpose of the study is to ensure adequacy of floodwall and dike grades, to determine channel velocities for use in design or riprap protection, and to determine if and where economies can be affected in construction of the project. A 1:120-scale model is being used to reproduce approximately 4000 feet of the Housatonic River and 16,000 feet of the Naugatuck River including 10 bridges, a floodwall approximately 4500 feet long, and riprap-lined dikes along the rivers.
- (f) Completed.
- (h) "Ansonia-Derby Local Protection Project, Naugatuck and Housatonic River, Connecticut; Hydraulic Model Investigation," TR H-69-4, April 1969.

(6861)

ARKANSAS, VERDIGRIS, AND GRAND RIVERS CONFLUENCE, MODEL STUDY.

- (b) U. S. Army Engineer District, Tulsa.
- (e) The purpose of the study is to investigate various plans of regulating structures and to develop modifications required for the development of a channel of adequate dimensions and satisfactory navigation conditions in the vicinity of the confluence of the three rivers. A movable-bed model with scale ratios of 1:120 horizontally and 1:80 vertically reproduces the Arkansas River from about river mile 457 to 462.5, plus about 4000 feet each of the Verdigris and Grand Rivers and adjacent overbank areas.
- (f) Report in progress.

(6862)

VAN BUREN REACH, ARKANSAS RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

- (b) U. S. Army Engineer District, Little Rock.
- (e) The purpose of the investigation is to study navigation conditions at the three bridges at Van Buren, Ark., to determine modification required in the existing railroad bridge, the interstate highway bridge under construction, and the proposed relocation of the highway bridge, and to develop a plan of regulating structures to provide satisfactory navigation conditions. The investigation is being conducted on a 1:120-scale, semifixed-bed and movable-bed model, reproducing about 4.2 miles of the Arkansas River and adjacent overflow areas, the mouth of Lee Creek, one railroad, and two highway bridges, and

- other structures that might affect flow conditions.
- (f) Report in progress.

(6864)

CHAGRIN RIVER, EASTLAKE, OHIO, MODEL STUDY OF WAVE PROTECTION STRUCTURES.

- (b) U. S. Army Engineer District, Buffalo.
- (e) The project provides for revision of river channel and installation of protective structures to minimize wave action generated in Lake Erie and allow satisfactory passage of flood flows through the river, which will enhance navigation of recreational small craft. The purpose is to: (a) study wave action and flood-flow conditions in the harbor entrance and lower reaches of the river with the proposed improvements and revisions installed in the model; (b) develop remedial plans for the alleviation of undesirable conditions with respect to wave action, navigation, and flood flows in the entrance and lower river as found necessary; and (c) determine whether suitable design modifications of the proposed plans could be made that would reduce construction costs significantly and still provide adequate protection from wave action and enhance flood-flow conditions. A 1:75-scale undistorted model, molded in cement mortar, will be used in the investigation. The model will include the lower portion of the river channel and connected slips and basins and adjacent areas of Lake Erie. Underwater contours will be reproduced to a prototype depth of about 25 feet and sufficient additional area will be included for generation of storm waves from the significant directions of approach. A 40-foot long wave machine and electrical wave-height measuring apparatus will be utilized in model operation. A water-circulating system will be included for simulation of the river flows.
- (f) Tests complete. Report in progress.

(6865)

CRESCENT CITY CALIFORNIA, THEORETICAL STUDY OF TSUNAMIS.

- (b) U. S. Army Engineer District, San Francisco.
- (d) Theoretical; applied.
- (e) The study consists of (a) the preparation of refraction diagrams of tsunamis which affect Crescent City, Calif., and (b) the estimation of the frequency of occurrence of tsunamis of different amplitudes from the different directions of approach to Crescent City, Calif. The wave refraction diagrams will provide information for a proposed hydraulic model study by showing the wave patterns and directions as the tsunami approaches Crescent City from various point sources in the Pacific. The frequency-of-occurrence study should provide part of the information necessary for determining the feasibility of various proposed protective schemes.
- (f) Complete.
- (h) "Theoretics in Design of Proposed Crescent City Harbor Tsunami Model," TR H-69-9, June 1969.

(6866)

HUMBOLDT BAY, CALIFORNIA, MODEL STUDY OF DESIGNS FOR JETTY REPAIRS.

- (b) U. S. Army Engineer District, San Francisco.
- (e) The entrance to Humboldt Bay, Calif., is protected by a system of rubble-mound jetties. The seaward ends of these jetties are subjected to the attack of westerly storm waves generated in the Pacific Ocean. The purpose of the study is to determine the stability of designs proposed for repairing the head or seaward ends of the existing damaged jetties. A stability model study is being conducted in the

WES 250-foot long by 50-foot wide by 4.5-foot deep flume. A model scale of 1:50 was selected and only the north jetty head was reproduced in the model. The seaward bottom topography was reproduced by molding a 2-inch thick concrete-crusted slope of 1:50 from -66 to -48 feet mllw and a slope of 1:10 from -48 to -36 feet mllw. The immediate head was reproduced with an average of 12-ton stone from -36 feet mllw to the crest. Model waves are generated by a paddle-type wave machine, and are measured and recorded electrically.

(6868)

MISSION BAY, CALIFORNIA, MODEL STUDY OF HARBOR DESIGN.

- (b) U. S. Army Engineer District, Los Angeles.
- (e) The purpose of the study is to determine the relative effects inside the harbor of waves of various magnitudes that approach the harbor site from the more significant storm directions, and to develop remedial plans as required to relieve any undesirable wave action in Quivera Basin and Glen Rick Cove. The three-dimensional wave action model is molded in cement mortar to an undistorted scale of 1:100, model to prototype. The model reproduces the entrance channel, Quivera Basin, Glen Rick Cove, and the underwater contours to an offshore depth of 60 feet. Sufficient additional offshore area is included to permit generation of waves from all critical directions. The total area reproduced in the model is approximately 15,500 square feet, representing about 5.6 square miles in nature. Waves in the model are generated by a 60-foot long, plunger-type wave machine.

- (f) Completed.
- (h) "Wave Action in Mission Bay Harbor, California; Hydraulic Model Investigation," TR H-69-8, June 1969.

(6869)

PORT SAN LUIS, CALIFORNIA, MODEL STUDY OF HARBOR MODIFICATIONS.

- (b) U. S. Army Engineer District, Los Angeles.
- (e) It is proposed that the existing harbor be modified to provide a safe, year-round, smallcraft mooring area for approximately 1500 pleasure craft and 240 commercial fishing boats. The proposed mooring area would be protected by four breakwater structures with a total length of approximately 6600 feet, and access to the harbor would be through two 400-foot entrances. The purpose is to: (a) study wave action in the harbor for existing conditions and with the proposed harbor revisions installed; (b) develop remedial plans for alleviation of undesirable wave action and navigation conditions in the inner harbor and entrance channels as necessary; (c) determine whether suitable design modifications of the proposed plans could be made that would reduce construction costs significantly and still provide adequate protection from wave action; and (d) study the effects of the proposed revisions on wave conditions at the Union Oil Company Pier. The three-dimensional wave-action model was molded in cement mortar to an undistorted scale of 1:100, model to prototype. The model reproduced the entire harbor area and underwater contours to an offshore depth of 60 feet. Sufficient additional offshore area was included to permit generation of test waves from all critical directions of wave approach. The total area reproduced in the model was approximately 12,250 square feet, representing about 4.4 square miles in nature. Waves in the model were generated by a 60-foot long wave machine, and wave-height data were

secured by the use of electrical measuring and recording apparatus.

- (f) Completed.
- (h) "Design for Expansion of Port San Luis, California; Hydraulic Model Investigation," TR H-69-6, April 1969.

(6870)

VERMILION HARBOR, OHIO, MODEL STUDY.

- (b) U. S. Army Engineer District, Buffalo.
- (e) The purpose of the study is to determine the optimum size, location, and orientation of proposed wave protection structures at the entrance to Vermilion Harbor. A 1:75-scale undistorted model, molded in cement mortar, was used in the investigation. The model included the harbor and adjacent areas of Lake Erie. Underwater contours were reproduced to prototype depth of about 25 feet, and sufficient additional area was included for generation of storm waves from the significant directions of approach. A 50-foot long wave machine and electrical wave-height measuring apparatus were utilized in model operation.
- (f) Tests complete. Report in progress.

(6871)

BOEUF RIVER, BIG AND COLEWA CREEKS, ARKANSAS AND LOUISIANA, MODEL STUDY OF LOW WATER WEIRS.

- (b) U. S. Army Engineer District, Vicksburg.
- (e) The purpose of the study is to test several plans to develop an effective, economical drop structure; to study flow conditions and determine protective stone requirements. A 1:20-scale model reproducing one-half the channel section through a low water weir was used to test different drop structures. The weir was constructed of sheet metal. Limestone rock with specific gravity of 2.63 was used to simulate riprap. The downstream channel was molded in sand during early tests and in coal during later tests. A second 1:20-scale section model was constructed in a 2.5-foot wide glass flume for more general riprap tests.
- (f) Completed.
- (h) "Low-Water Weirs on Boeuf and Tensa Rivers, Bayou Macon, and Big and Colewa Creeks, Arkansas and Louisiana; Hydraulic Model Investigation," TR H-69-13, October 1969.

(6872)

CANAL DENSITY CURRENTS.

- (b) USAE Nuclear Cratering Group.
- (d) Experimental; applied research.
- (e) The purpose is to determine if density currents will be a significant parameter to be considered in presently proposed sea-level canals. The study, complemented by theoretical predictions based on the results of the laboratory study, is directed to determining velocity conditions resulting from density differences within the canal and how the velocities relate to navigation requirements for the canals. The study was conducted in a plastic flume connecting two tidal basins with a side channel located at the center of the flume to simulate a freshwater river intercepting the canal. Test procedure included the adjustment of the desired tides in each basin to simulate the desired flows in the flume, and the introduction of the freshwater flows of interest into the side channel and monitoring the resulting salinities, velocities, and tidal heights throughout the system. The results formed the basis for prediction of the resulting velocity profiles of the prototype for specific tidal and freshwater inflow conditions.
- (f) Completed.
- (h) "Canal Density Currents," MP H-69-6, May 1969.

(6873)

NUCLEAR EXCAVATED CHANNELS.

- (b) USAE Nuclear Cratering Group.
- (d) Theoretical and experimental; applied research.
- (e) When nuclear explosives are used to excavate a desired navigation channel through terrain of varying elevation, the size and charge placement will result in a channel of varying widths and depths. These resulting irregularities of the channel become significant when the hydraulics of the channel are considered. Problems result in predicting the head loss through the channel as well as velocity distribution throughout the channel. The purpose of the study is to provide, for a limited range of sizes and shapes of navigation channels formed by the use of nuclear explosives, an indication of the Manning's n that could be used to determine discharges through the channels. In addition, the study included consideration of the current velocity distributions that might be expected to exist in the channels. The study was conducted in two flumes constructed within WES Coastal Inlet Research Facility B. The first flume was used to define the head loss and velocity distribution within a straight uniform channel of cross-sectional shape similar to a channel resulting from a nuclear explosive. The second flume was used to define the head loss and velocity distribution of a channel with expansions and contractions of interest. The channel in the second flume had a mean hydraulic radius and mean cross-sectional area duplicating the same parameters of the straight uniform channel. The resulting difference between the tests in the straight channel and the nonuniform channel provided a basis for predictions of the effects of expansions and contractions. All work was conducted in model dimensions with the model results extended to prototype ranges for a final prediction.
- (f) Completed.
- (g) Analysis of the data from the flume, as well as previous generally applicable test data and results, shows that for prototype channels with expansions and contractions similar to those subjected to investigation, Manning's n can be estimated from the equation as follows:

$$n_2 = (0.732n_1^2 + 4.43 \times 10^{-4}R^{1/3})^{1/2}$$

where n_2 = effective Manning's n of cratered channel; n_1 = effective Manning's n of the same channel without expansion and contraction; R = mean hydraulic radius, ft.

- (h) "Hydraulic Characteristics of Nuclear Excavated Channels," MP H-69-5, May 1969.

(6874)

SUMMERSVILLE DAM, MODEL STUDY OF HOWELL-BUNGER VALVE.

- (b) U. S. Army Engineer District, Huntington.
- (e) The Summersville Dam outlet works consist of a 29-foot diameter tunnel 1700 feet long discharging through a manifold system of three 11-foot diameter conduits averaging 210 feet in length. The outflow is controlled by a 9-foot Howell-Bunger valve at the downstream end of each 11-foot conduit. Flow from the valve is confined by a 20-foot diameter hood. Operation of the prototype valve resulted in a portion of the conical jet being turned upstream into the valve pit after its impingement on the hood. Model tests are being conducted to study the adequacy of various schemes in eliminating or reducing the undesirable backslash. The investigation was conducted on a 1:20.6-scale model that reproduced the valve, valve pit, hood,

and 100 feet of the approach tunnel. Piezometers were located in the approach tunnel to determine pressures in the area of the upstream butterfly valve. The valve pit and hood were constructed of clear plastic to permit observation of the backslash.

- (f) Tests completed; report in progress.
- (g) Tests indicated that approximately 60 percent of the backslash could be eliminated by installing 3-foot long 10WF 49 beams on 10-degree centers around the inside periphery of the hood. The beams reduced backslash by intercepting the jet, creating turbulence, and increasing the demand and entrainment of air. Various collector rings located upstream of the beams were found to be beneficial in reducing the backslash to a satisfactory degree as well as a scheme which utilized the beams in a diverging, conical arrangement. Less backslash was observed as the hood diameter was increased.

(6875)

RIPRAP REQUIREMENTS IN CHANNELS.

- (b) Office, Chief of Engineers.
- (e) Theoretical and experimental investigations regarding the adequacy of various sizes of crushed stone and gravel in resisting flow in straight and curved reaches of trapezoidal channels of varying hydraulic radii will be conducted to obtain basic data for development of a satisfactory theory and appropriate design criteria regarding the stability of stone in flowing water.

(7154)

ALUM CREEK DAM, ALUM CREEK, OHIO, MODEL STUDY OF SPILLWAY.

- (b) U. S. Army Engineer District, Huntington.
- (e) Plans call for an earth-fill dam about 10,000 feet long, a three-bay gated overfall, a hydraulic-jump type stilling basin, and facilities for low-flow and municipal water supply. The purpose of the study is to develop the most satisfactory design for the spillway approach and abutments, determine the need, extent, and design of riprap in the approach and outlet channels, and determine the adequacy of the stilling basin design. A 1:60-scale, undistorted model that reproduced 720 feet of the approach and 1200 feet of the exit areas, the spillway, nonoverflow sections, and portions of the earth embankment was utilized to conduct the study.
- (f) Tests are complete; final report is in progress.

(7155)

ARKANSAS RIVER DAMS, MODEL STUDY OF SPILLWAY GATES.

- (b) U. S. Army Engineer District, Little Rock.
- (e) A series of navigation locks and dams is being constructed on the Arkansas and Verdigris Rivers to provide a navigable channel from the Mississippi River to the vicinity of Tulsa, Okla. The comprehensive plan includes a number of low-head dams with similar features. The spillway sections of these dams will consist of low sills, surmounted by 60-foot wide tainter gates, located in the main channel of the river. The purpose of the study is to verify the effectiveness of completed and proposed gate lip modifications on the Arkansas project in eliminating gate vibrations. A 1:12-scale model that reproduces one full gate bay with the gate members and shape accurately reproduced, the two adjacent half bays with schematic gates, the spillway crest, two crest piers, and the stilling basin in a 12-foot wide flume is being used.
- (f) Construction of the model has been completed.

(7156)
BRANCHED OAK DAM, NEBRASKA, MODEL STUDY OF OUTLET WORKS.

- (b) U. S. Army Engineer District, Omaha.
- (e) The uncontrolled outlet works will consist of a hooded, vertical-shaft intake structure (throat section 6 by 12 feet), a 6-foot diameter conduit, and conventional hydraulic-jump type stilling basin. The purpose of the study is to verify the performance of the structure and particularly to ensure against undesirable flow characteristics, such as surging during transition of flow control from weir to conduit, which tend to incite excessive vibration of the structure. A 1:10-scale model of the Branched Oak outlet works reproduced the intake, 10,000 square feet of approach area, the 380-foot long conduit, and 200 feet of exit channel. The intake and tunnel were constructed of plastic to permit observation of flow. The stilling basin and appurtenances were constructed of wood chemically treated to prevent expansion. The exit areas were molded of concrete to reproduce existing contours. Piezometers were located in the intake and tunnel to permit observations of pressures. A 1:10-scale model of the proposed Cottonwood Springs outlet works was also utilized in subsequent and extended tests.
- (g) Both models indicated undesirable flow characteristics such as nappe flutter, sloshing, and gulping which tended to vibrate the structures. Model tests indicated that the flutter could be eliminated by rounding the weir crests; the nappe sloshing could be eliminated by providing a divider wall between and parallel to the weir crests; and the gulping beneath the cover plate eliminated by placing the cover plate at an elevation above that of the upper pool when the conduit begins to control flow. Final report in progress.

(7157)
CLARENCE CANNON DAM, SALT RIVER, MISSOURI, MODEL STUDY OF SPILLWAY.

- (b) U. S. Army Engineer District, St. Louis.
- (e) The spillway (crest elevation 600.0) will consist of four 50-foot wide bays. The purpose of the study is to investigate approach and exit flow conditions, discharge characteristics of the structure, and characteristics of stratified flow over the weir proposed upstream of the powerhouse intakes. Model tests were conducted on a 1:50-scale general model that reproduced the entire spillway and 1800 feet of the approach and 2300 feet of the exit areas. Approach and exit areas were molded in concrete to existing contours. The spillway and powerhouse were constructed of sheet metal.
- (f) Tests complete. Final report in progress.

(7158)
CLINTON AND FORT SCOTT OUTLET WORKS MODEL STUDIES, WAKARUSA AND MARMATON RIVERS, KANSAS.

- (b) U. S. Army Engineer District, Kansas City.
- (e) The purpose of the study is to observe the hydraulic phenomena of the modified oblong-shaped conduits, and verify the adequacy of the outlet works stilling basin and riprap requirements. Model tests will be conducted on a 1:16-scale model which will reproduce a schematic intake structure, the modified oblong conduit, the outlet works stilling basin, and 800 feet of the exit channel.

(7159)
DRAG COEFFICIENTS FOR STILLING BASIN BAFFLES.

- (b) Office, Chief of Engineers.
- (e) An experimental investigation is being made of the drag forces on baffle blocks located through-

out the length of a hydraulic jump. Forces are measured directly by means of load cells. Downstream water-surface elevations and velocities are used as performance criteria and are measured electronically. Instantaneous pressures on the blocks indicate cavitation potential. The purpose of the study is to investigate baffle blocks, which improve the performance of hydraulic jumps used as energy dissipators; and to develop drag coefficients for practical baffle geometries that will permit rational designs without recourse to model studies.

A 4-foot wide flume was constructed with a sliding floor and 2.5-foot high conventional spillway crest. The force box with floating plate and load cells was constructed in the floor. This arrangement permitted an infinite variety of block locations to be readily made. A light-bulb point gage was used to measure inlet depths. A wave rod and recorder measured downstream depths and wave heights. Miniature pressure transducers were located in the baffle blocks to record instantaneous pressures. An electronic pressure-cell pitot tube was also devised to record downstream velocity profiles.

- (g) The drag force generally was found to increase as the block height increased, the blocks moved near the jump toe, the flow blockage increased, and the second row moved near the first. The maximum drag force in the region of best water-surface profile was employed as the optimization criterion and generally resulted in near optimum jump length and wave heights. Optimum block height ratio increased and the location ratio decreased as the Froude number increased. Both trends were shown to be experimentally and physically plausible. The optimum flow blockage was near 0.50 and little evidence was uncovered in support of a second block row to improve those performance variables of interest.

(7160)
OAKLEY RESERVOIR, SANGAMON RIVER, ILLINOIS, MODEL STUDY OF SPILLWAY.

- (b) U. S. Army Engineer District, Chicago.
- (e) The purpose of the study is to develop the most desirable hydraulic features of the spillway and stilling basin and to determine the stability of the proposed riprap and the effect of the downstream highway embankment on discharge characteristics. Model tests were conducted on a 1:60-scale general model which reproduces about 1800 feet of approach channel and 1700 feet of exit channel, and the dam including the spillway and nonoverflow sections.

(7161)
RAYSTOWN RESERVOIR, JUNIATA RIVER, PENNSYLVANIA, MODEL STUDY OF GATED SPILLWAY.

- (b) U. S. Army Engineer District, Baltimore.
- (e) Raystown Reservoir's two-gated spillway designed for the Juniata River, Pa., will be checked for adequacy of design; the primary concern is the possibility of surges at the gates. The purpose is to determine if surges occur on the spillway gates, check overall performance, obtain discharge characteristics of the spillway, develop the flip bucket, and verify riprap protection of left bank downstream. A 1:60-scale model reproduced the gated spillway, flip bucket, warmwater intakes with control gate, tunnel and chute and portions of the upstream and downstream approaches. All model components were functional as required to simulate prototype conditions.
- (f) Tests complete. Report in progress.

(7162)

ROWLESBURG DAM, CHEAT RIVER, WEST VIRGINIA, GENERAL MODEL STUDIES.

(b) U. S. Army Engineer District, Pittsburgh.

- (c) The project will provide flood-control protection and will include such features as high head, large discharge per unit length of spillway, high velocity sluice outflow, and provision for water-quality control. The spillway will be controlled by seven 45-foot wide crest gates. Six sluices will be provided for reservoir control. Spillway design flood will be about 320,000 cfs and capacity of the flood-control sluice with reservoir at spillway crest would be about 32,200 cfs; maximum flow scheduled through the water-quality tower and sluice, 2500 cfs. The purpose of the investigation is to study hydraulic performance of the spillway, to verify the adequacy of the spillway and sluices for both separate and combined flow operation, to verify and/or refine the stilling basin design, and to study approach and exit channel conditions; to evaluate the effectiveness of the water-quality control tower and sluice in selectively withdrawing water from desired levels; and to investigate pressures in the sluice intake. A 1:60-scale comprehensive model reproduced a 1500-foot section of approach channel, the entire 375-foot wide gated spillway and abutments, the six 10-foot high by 5.67-foot wide low level flood-control sluices, the stilling basin, and a 1500-foot section of the exit channel. The spillway, tainter gates, sluices, and spray and basin walls were constructed of sheet metal. The water-quality tower was reproduced in plastic. The stilling basin floor, baffles, and end sill were reproduced in waterproofed wood. The surface of the model, exclusive of structures, was molded in cement mortar to sheet metal templates. A 1:20-scale model reproduced a single sluice. The sluice was reproduced in plastic and was attached to a pressure tank to permit testing under a full range of upper pool and discharge conditions.
- (f) Tests complete. Report in progress.

(7163)

BARNEGAT INLET, NEW JERSEY, MODEL STUDY.

(b) U. S. Army Engineer District, Philadelphia.

- (c) The purpose is to evaluate the effectiveness of a proposed multiphase improvement plan for establishing a stable navigation channel through Barnegat Inlet. The model consists of a detailed reproduction of Barnegat Inlet and immediate surrounding ocean and bay. Tidal flows from the ocean and bay are reproduced at the respective ends of the model. Presently the model is molded in sand to a vertical scale of 1:60 and a horizontal scale of 1:300 to allow detailed investigation of the shoaling and scouring tendencies of the proposed plans. The plans were previously investigated in the fixed-bed concrete model to determine the effects of proposed improvement plans on current distribution throughout the inlet.

(7164)

COMPARISON OF MATHEMATICAL AND HYDRAULIC MODELS FOR HARBOR OSCILLATIONS.

- (b) Office, Chief of Engineers.
- (c) The Corps of Engineers has had some experience in the application of hydraulic models to the solution of harbor surge action problems. However, several mathematical models have been recently proposed to study this phenomenon. It is essential to evaluate these proposals since it is possible that generalized computer programs could be adopted or developed to analyze many harbor oscillation problems faster, cheaper, and more

reliably than traditional hydraulic models. The project will compare the various mathematical models for harbor surge action with each other and with hydraulic models. The goals of the investigation are (a) to determine which kinds of harbor problems can best be studied by the computer techniques, be solved by use of hydraulic model investigations, and be investigated by a combination of the two approaches; and (b) to systematically select the best computer program for future use by the Corps of Engineers. The electronic digital computers being used to execute the large programs of the various mathematical models are the GE 435 at the Waterways Experiment Station and the CEIR GE 600 at Bethesda, Md. The latter is accessed via the GE 115 at the Vicksburg District. Although the hydraulic model aspects of the study will not be begun until the second half of the coming calendar year, it is anticipated that existing models of the Waterways Experiment Station will be used. Preliminary studies have indicated that the existing Crescent City Harbor, Calif., model will be suitable for the bulk of the hydraulic model testing. This is a fixed-bed model with an undistorted scale of 1:125.

(7165)

ELIZABETH RIVER DIKE STUDY, CHANNEL MAINTENANCE.

(b) U. S. Army Engineer District, Norfolk.

- (c) The purpose of the study is to determine the effects of a proposed 11,250-foot dike constructed generally parallel to the channel and extending from the northeast corner of Craney Island disposal area to deep water on tides, currents, and shoaling in navigation channels and adjacent slips. An existing comprehensive model, with scale ratios of 1:1000 horizontally and 1:100 vertically, which correctly reproduced tides, currents, and salinities in James River and its important tributaries, was used for the tests.
- (f) Completed.
- (h) "Effects of Proposed Elizabeth River Dike on Tides, Currents, Salinities, and Shoaling; Hydraulic Model Investigation," MP H-69-13, Dec. 1969.

(7166)

GASTINEAU CHANNEL, ALASKA, TIDAL EQUALIZATION STUDY.

(b) Office, Chief of Engineers.

- (c) An analytical solution was developed to predict the tidal hydrograph behind a proposed highway fill across Gastineau Channel, Alaska, for various combinations of equalization structures. The purpose was to develop an adequate design of tidal equalization structures in the proposed highway fill. An existing hydraulic model of Gastineau Channel was used to develop input data for the analytical solution. Scales of the model are 1:500 horizontally and 1:100 vertically.
- (f) Report in progress.

(7167)

GRAYS HARBOR MODEL STUDY.

(b) U. S. Army Engineer District, Seattle.

- (c) At the present time, adverse current conditions are threatening to undercut the south jetty, causing expensive repair work or possible failure of the structure. The model investigation will deal with this problem along with other studies concerning realignment of the existing channel, pollution, and channel shoaling. The purpose is to investigate the complex interrelation involved in reconstruction of the north jetty at Grays Harbor, maintain a 30-foot channel between the north and south jetties, and determine possible modification in lengths of the north and south

- jetties to minimize shifting of the entrance channel southward to avoid undercutting the toe of the south jetty. In addition, a pending survey report investigation will consider the feasibility of increasing the depth of the presently authorized channel.
- A combination fixed-bed and movable-bed model which will include all of Grays Harbor, the Chehalis River to the head of the tidal influence, and a suitable area of the Pacific Ocean adjacent to the harbor entrance will be used to reproduce tides, tidal currents, littoral currents, wave action, density currents, and freshwater inflow. Linear scales proposed are 1:500 horizontally and 1:100 vertically.
- (7168)
JAMAICA BAY HURRICANE BARRIER STUDY, NEW YORK.
(b) U. S. Army Engineer District, New York.
- (e) The purpose of the study is to determine the effects of the structure (all tidal passages open) across Rockaway Inlet on the tides, currents, salinities, and dye dispersion patterns throughout Jamaica Bay for normal tidal conditions. If there are no major effects on the above-mentioned phenomena and maximum velocities through the navigation opening are not excessive, the plan will be subjected to hurricane surges to determine the amount of suppression obtained throughout Jamaica Bay.
- Jamaica Bay is a part of the New York Harbor complex and this area was included when the New York Harbor model was constructed some 12 years ago. Prior to undertaking this study, the Jamaica Bay portion of the existing model was removed and rebuilt to surveys made in 1967. Particular attention was given to the areas between 0.0 and +10.0 feet mhw to ensure an accurate reproduction of the tidal prism within the bay. The scale ratios, model to prototype, are 1:1000 horizontally and 1:100 vertically.
- (7169)
JAMES RIVER TWENTY-FIVE FOOT CHANNEL SHOALING STUDIES.
(b) U. S. Army Engineer District, Norfolk.
- (e) The purpose is to conduct tests involving plans to reduce shoaling in the existing 25-foot channel (dikes, spoil disposal areas, sediment traps, and channel realignments). An existing comprehensive model, with scale ratios of 1:1000 horizontally and 1:100 vertically, which correctly reproduces tides, currents, and salinities in the James River and tributaries, was used for the tests.
- (7170)
MORICHES INLET, NEW YORK, MODEL STUDY.
(b) U. S. Army Engineer District, New York.
- (e) The purpose is to determine the most feasible method of maintenance of a navigation channel through the inlet as well as a method of bypassing sand around the inlet. The model consists of detailed reproduction of the inlet and area immediately surrounding the inlet. The bay behind the inlet is schematically reproduced. At the present time, the model is molded in sand to a vertical scale of 1:160 and a horizontal scale of 1:300 for investigation of the proposed plans. Previously, the model was molded in concrete for evaluation of proposed plans on tidal effects and current patterns.
- (7171)
SHOALING AT HARBOR ENTRANCES, MODEL STUDY.
(b) U. S. Army Engineer Districts, Memphis, Vicksburg and New Orleans.
- (e) Periodic dredging is required to maintain adequate depths at entrances to most harbors on the Mississippi River. The purpose of the study is to develop methods of eliminating or reducing shoaling at entrances to harbors on the Mississippi River. The investigation is being conducted in an existing model modified for the study. The facilities include a channel about 12 feet wide and 200 feet long including two bends connected by a relatively long, straight reach with provision for constructing harbor entrances at various locations with respect to channel alignment. The study is of the movable-bed type with a crushed coal bed material.
- (7172)
SHREWSBURY RIVER, NEW JERSEY, MODEL STUDY.
(b) U. S. Army Engineer District, New York.
- (e) A small-boat channel across the southern end of Sandy Hook Peninsula is proposed in order to provide commercial and private small-boat users a shorter and safer route from Shrewsbury and Navesink Rivers and Sandy Hook Bay to the ocean. The purpose of the study is to determine what effect the small-boat channel across Sandy Hook Peninsula would have on tides, currents, salinities, shoaling, and dye dispersion patterns in the Sandy Hook Bay and Shrewsbury and Navesink Rivers. The model is an addition to the existing New York Harbor model which is of the fixed-bed, silt-injection type with linear-scale ratios, model to prototype, of 1:100 vertically and 1:1000 horizontally. The model reproduces the entire tidal portion of Shrewsbury and Navesink Rivers and adjoining overbank areas up to +20 feet msl. Tides and tidal currents will be reproduced by automatic tide-control mechanisms, and freshwater discharges from all significant tributaries will be introduced by means of Van Leer weirs. Observed prototype salinities will be reproduced in the model, and provisions will be made to inject silt into the model and measure silt deposits on the model bed for shoaling studies. Studies of the dispersion of different contaminants will be made by releasing permanent dyes and tracing their movement and concentration with respect to time after release.
- (7173)
BANKHEAD LOCK, BLACK WARRIOR RIVER, ALABAMA, MODEL STUDY OF NAVIGATION CONDITIONS.
(b) U. S. Army Engineer District, Mobile.
- (e) The purpose of the study is to determine the optimum location for a new 670-foot long by 110-foot wide lock at Bankhead with respect to the existing dam. With the adopted lock site the effects of a cofferdam downstream on present river traffic were investigated. The model was also used to test surges in the upstream approach canal to the lock.
- A 1:100-scale model of a 3-mile reach of Black Warrior River including the existing powerhouse, dam, and locks was constructed to simulate river navigation conditions. These hydraulic navigation conditions and excavation plans were used for comparing proposed new lock locations.
- (f) Tests complete. Report in progress.
- (7174)
BARKLEY LOCK, CUMBERLAND RIVER, KENTUCKY, LOCK PROTOTYPE TESTS.
(b) U. S. Army Engineer District, Nashville.
- (e) The lock has clear dimensions of 110 by 800 feet, a maximum lift of 73 feet, and a normal lift of 57 feet. The chamber is filled and emptied through two 16- by 16-foot culverts and a split-

lateral system. Hydraulically operated tainter valves control flow into and out of the lock chamber. The purpose is to measure hawser forces, lock water-surface elevations and slopes, average and fluctuating pressures, valve performance, and auxiliary measurements. The effects of valve speed, single and nonsynchronous valve operation, overfilling, and air venting on hawser forces, valve and culvert pressure fluctuations, valve hoist loads, and vibrations were measured. Dynamometers at each hawser were used to measure hawser forces created by the filling and emptying of the lock. Potentiometers on mountings measured transverse and longitudinal tow motion in the lock, miter gate opening, and filling and emptying valve positions. Pressure cells were utilized for determining air vent discharge, valve face pressures, lock chamber and valve well water-surface elevations, and culvert pressures. Lock water-surface elevations and slopes were measured using a differential pressure cell and a pneumatic system. Valve acceleration was measured for determining the frequency and amplitude of valve vibration. Strain gages mounted on the stem of the filling valve measured hoist load. This was also measured with pressure cells at the valve hoist cylinder. Electrical probes in the culvert measured the presence of air or vapor cavities along the culvert roof. Piezometers were also utilized in the measurement of culvert pressures.

(7175)

FORCES ACTING ON SECTOR GATES UNDER REVERSE HEAD CONDITIONS.

(b) U. S. Army Engineer District, New Orleans.

(e) Sector gates on several locks in the vicinity of New Orleans, La., have experienced difficulties in operating under reverse head conditions. Lock gates on Bayous Boeuf and Calcasieu stall during opening and overhaul the machinery during closing. The purpose of the study is to determine the forces acting on sector gates under reverse head conditions as built, and develop feasible modifications for elimination of operating difficulties. A 1:20-scale model of one set of sector gate leaves (Bayou Boeuf) including a portion of the lock walls was used in the study.

(f) Tests complete. Report in progress.

(7176)

DEVIL'S ISLAND REACH, MISSISSIPPI RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

(b) U. S. Army Engineer District, St. Louis.

(e) The purpose is the development of the most economical and effective plan of regulating structures that would provide a channel of adequate depth and alignment for navigation without excessive maintenance.

A movable-bed model with scales of 1:400 horizontally and 1:100 vertically reproducing the reach of the Mississippi River between miles 55 and 68 and the adjacent overbank areas is being used.

(7177)

DIKE DESIGN INVESTIGATION.

(b) U. S. Army Engineer Districts, Memphis, Vicksburg and New Orleans.

(e) Stabilization and improvement of the Mississippi River will involve the use of many miles of dikes. The purpose of the study is to determine the factors affecting the performance of dikes and dike systems to provide indications as to the relative effectiveness of the various factors and provide a basis for the development of principles for use in the design of dikes. The investigation is being conducted in a 40-foot wide by 200-foot long

by 1.5-foot deep flume which provides flexibility for the development of various types of river problems. The study is of the movable-bed type with a crushed coal bed material.

(7178)

ST. LOUIS HARBOR, MISSISSIPPI RIVER, MODEL STUDY OF NAVIGATION CONDITIONS.

(b) U. S. Army Engineer District, St. Louis.

(e) The project involves the improvement of the Mississippi River for navigation in the vicinity of St. Louis. The purpose of the study is to investigate various plans for the development of a channel of adequate dimensions and satisfactory navigation conditions in the vicinity of St. Louis. A movable-bed model with scale ratios of 1:250 horizontally and 1:100 vertically reproducing the Mississippi River from about river mile 169.0 to mile 190.8 and adjacent overbank areas is being used.

(7179)

CRESCENT CITY, CALIFORNIA, FLUME TESTS FOR TSUNAMI STUDY.

(b) U. S. Army Engineer District, San Francisco.

(e) The purpose of the study is to determine design parameters for a three-dimensional model of Crescent City, Calif., which would be used to develop an optimum design for the proposed tsunami barrier, and to approximate the effect on runup elevation that would be reached with a barrier in place in order to provide a basis for preliminary re-evaluation of the plan to determine the advisability of continuing the investigation. Preliminary tests were conducted in a concrete flume 5 feet wide and 100 feet long using a 5-foot wide vacuum-type wave generator to reproduce a single wave representative of a tsunami wave in the prototype. Additional tests are being conducted in a concrete and glass-sided flume 2 feet wide, 166 feet long, and 4.5 feet deep with the wave generator revised to a 2-foot width. Electrical apparatus is used to control the wave generator and to measure and record wave heights in the flume.

(g) Tests were conducted to determine how runup is affected by distortion of model scale. These tests entailed measuring wave runup with three distorted scales. The runup measurements were taken using a wave period of 28 minutes (nature) and several different wave heights for each slope. Also, tests were conducted to determine whether runup is significantly affected by a change in wave period. The results of these tests will be compared with test results obtained with the same model arrangement and a prototype wave period of 28 minutes. Tests were also conducted to determine an approximate minimum crown elevation to prevent all but minor overtopping of the tsunami barrier.

(7180)

OAK HARBOR, WASHINGTON, MODEL STUDY OF FLOATING BREAK-WATER.

(b) U. S. Army Engineer District, Seattle.

(e) The purpose of the study is to determine the wave attenuation characteristics of the proposed break-water design in reducing wave conditions at Oak Harbor and to determine the forces developed in the mooring lines.

A two-dimensional model study is being conducted in the WES 119-foot long, 5-foot wide, and 4.0-foot deep wave flume. A model scale of 1:10 is being used for the study in which only one unit of the prototype structure, 42 by 10 by 7 feet, has been reproduced geometrically and dynamically.

A flat bottom flume is being used since most of the wave conditions tested are deepwater waves. Model waves are generated by a vertical-displacement type plunger connected to a variable-speed drive mechanism, and are measured and recorded electrically.

(7181)

EAST RIVER TUNNEL, NEW YORK, MODEL STUDY.

- (b) U. S. Army Engineer District, New York.
- (e) The project provides for a tunnel across the East River between 63rd Street on the Manhattan side and 41st Avenue on the Long Island side, and includes a permanent protective blanket over the tunnel constructed to -45 feet mlw. During construction of the tunnel an additional temporary protective blanket constructed to -35 feet mlw with a 90-foot wide movable section extending to -5 feet mlw will be required. The purpose of the study was to determine the effects of both the permanent and temporary protection blankets (described above) on tides and currents in East River. These data will be used for design purposes and for determination of permanent and temporary effects on navigation.
- Tests were conducted in the existing fixed-bed, comprehensive model of the New York Harbor complex. The model was constructed to linear scale ratios, model to prototype, of 1:100 vertically and 1:1000 horizontally.
- (f) Completed.
- (h) "Effects of Temporary and Permanent Blankets on Tides and Currents in the East River; Hydraulic Model Investigation," MP H-69-7, April 1969.

(7182)

LIMITING VALUES OF WAVE REFRACTION COEFFICIENTS.

- (b) Office, Chief of Engineers.
- (e) The development of a more reasonable theory for wave refraction involving initially the consideration of finite amplitude waves in shallow water and eventually the possible development of non-linear theory. The purpose is to determine the maximum value of the wave refraction coefficients in a zone of strong convergence as a function of wave height and period, and to develop a higher order theory for wave refraction.
- A three-dimensional wave flume 20 feet wide by 84 feet long by 3.5 feet deep will be used in the study. Wave-height measurements will be made with a network of 18 wave gages installed so as to cover the area of interest. A 20-foot long wave machine at one end of the flume will generate the test waves.
- (g) Refraction coefficients as high as 6.4 were computed for the contours selected for reproduction in the test flume.

(7183)

SALAMONIE DAM, INDIANA, PROTOTYPE FLIP BUCKET JET TRAJECTORY TESTS.

- (b) U. S. Army Engineer District, Louisville.
- (e) The outlet works are a three-gated structure and two 30-inch diameter, low-flow bypass pipes, all discharging into a 16-foot diameter conduit leading to a flip bucket along the base of the right abutment. The purpose is to measure the velocity profile at a location near the lip of the bucket and to measure the trajectory of the jet.
- Basic prototype instrumentation includes: velocity probe, pressure gages, and mercury manometer; photographic equipment and background targets; staff gages, and a USGS discharge measuring station.

(7184)

SEA-LEVEL CANAL TRANSIT CAPACITY STUDY.

- (b) Office, Chief of Engineers.
- (e) Development of a digital computer program which predicts sea-level canal transit capacities as a function of canal geometry, flow conditions in the canal, and characteristics of the ships that will use the canal. Also the development of a simple algebraic equation which, hopefully, gives roughly equivalent results. The purpose is to develop the capability to predict sea-level canal transit capacities.
- (f) Completed.
- (h) "An Analytical Model to Predict Ship Transit Capacities of Sea-Level Canals," MP H-69-10, September 1969.
- "A Statistical Model to Predict the Transit Capacity of Sea-Level Canals," MP H-69-12, December 1969.

(7185)

EROSION CONTROL AT STORM-DRAIN OUTLETS.

- (b) Office, Chief of Engineers.
- (e) A laboratory investigation to determine the scour characteristics of sand and various sizes of crushed stone resulting downstream of various shapes of culverts with various flow conditions. The purpose is to develop riprap design criteria for culvert and storm-drain outlets.
- Relatively short sections of circular culverts with diameters of 0.125, 0.224, 0.333, and 1.00 feet located at the upstream end and center of a 16-foot wide, 5.5-foot deep, and 40-foot long test flume containing sand and/or crushed stone of uniform size ranging from 1/4- to 6-inch diameters were used to investigate scour tendencies for various tailwater conditions with outlet velocities up to 20 fps. Circular, arch, rectangular, and box-shaped sections of equal areas were used to investigate the effect of shape upon the scour characteristics.
- (g) Scour holes, produced by the discharge of various flows of several durations through culverts of various shapes and sizes, were observed and contoured. These data were obtained for several tailwater conditions and were used to develop generalized expressions describing the maximum length, width, depth, and volume of scour as functions of the flow duration and the Froude number of flow at the culvert outlet. Dimensionless scour profiles and cross sections, for low and high tailwater conditions, were also developed. Riprap blankets of various configurations and stone sizes were tested with several culvert sizes and shapes and various tailwater conditions to determine when displacement or failure occurred. The results were used to develop generalized relations to describe the stone size and appropriate blanket configuration required to prevent blanket failure and soil erosion, respectively, at a culvert or storm-drain outfall.

(7186)

PECO THERMAL STUDIES, DELAWARE RIVER MODEL.

- (b) U. S. Army Engineer District, Philadelphia.
- (e) Government antipollution regulations limit the allowable increase in normal river water temperature as the result of the continued activities of all water users. The Philadelphia Electric Company (PECO) is interested in knowing the thermal contribution its existing power plants are making to water temperatures in the Delaware Estuary and the projected increase in thermal contributions resulting from the operation of several additional power plants required to satisfy future power requirements in the area. Waterways Experiment

Station personnel prepared the model, conducted the tests, and made all necessary measurements. Data analysis and reporting will be done by the Alden Research Laboratory. The purpose is to determine the thermal effects of the existing PECO power plants and the additional thermal contribution resulting from the operation of six atomic-powered generating plants proposed for the future.

The tests were conducted in the existing fixed-bed comprehensive Delaware River model. The model is constructed to linear scale ratios, model to prototype, of 1:100 vertically and 1:1000 horizontally. The thermal scale ratio is 1:1.

(f) Suspended.

U. S. DEPARTMENT OF COMMERCE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION, ATLANTIC OCEANOGRAPHIC AND METEOROLOGICAL LABORATORIES, Physical Oceanographic Laboratory, 901 South Miami Avenue, Miami, Florida 33130. Donald V. Hansen, Director.

(7008)

GULF OF MEXICO AND ADJACENT REGIONS TIDAL REGIME.

- (b) Institute of Marine Sciences, University of Miami. Recently the project became part of CICAR (Cooperative Investigations of the Caribbean and Adjacent Regions), IOC-UNESCO.
- (c) Bernard D. Zetler.
- (d) Theoretical and field investigation, applied research.
- (e) To develop hypotheses for tidal regime in the area leading toward improved predictions of tide and tidal currents.
- (g) Hypotheses have been developed accounting for the diurnal and semi-diurnal tidal regimes, respectively, and a field program has been proposed to test these hypotheses.
- (h) "Tidal Modulation of the Florida Current Surface Flow," Zetler and Hansen, Bulletin of Marine Science, in press.

(7009)

DEEP-SEA TIDES.

- (b) Walter Munk, U. of California, and David Cartwright, National Institute of Oceanography, Great Britain.
- (c) Bernard D. Zetler.
- (d) Experimental, basic research.
- (e) In support of the Working Group on Deep-Sea Tides (SCOR, UNESCO, and IAPSO). Tide measurements will be obtained and analyzed for use in preparing and evaluating global tide models. Because of the difficulty and expense in obtaining such measurements, it is important that the analysis of the data be as comprehensive and meaningful as is possible.
- (g) An analysis procedure has been developed and recommended to the International Working Group.
- (h) "A Suggested Procedure for the Analysis of Pelagic Tidal Measurements," Cartwright, Munk and Zetler, EOS, 50, 7, 472-477, July 1969.
- "Tidal Constants Derived from Response Admittances," Zetler, Cartwright and Munk, Proc. Sixth Int. Symp. on Earth Tides, Strasbourg, 1969, in press.

(7010)

FLORIDA CURRENT DYNAMICS.

- (b) Jointly with Carl Wunsch, Massachusetts Institute of Technology.
- (d) Theoretical and field investigation; applied research.
- (e) Investigation of various aspects of Florida Cur-

rent dynamics including variability in flow as determined from sea level records, scales of motion from drogue studies, determination of axis from water temperature measurements, and determination of circulation patterns from oceanographic station data, all leading toward environmental prediction systems.

- (g) The Florida Current flow has been found to be less variable than in previous conceptions, a descriptive report of circulation in the Cay Sal Bank area is in press, trajectories, divergence, and dispersion have been studied by means of parachute drogues, and considerable data has been gathered relative to optimizing tanker travel times through water temperature observations to locate the axis of the stream.
- (h) "Fluctuations of the Florida Current Inferred From Sea Level Records," Wunsch, Hansen and Zetler, Deep-Sea Research, Supplement to Vol. 16, 447-470, 1969.
- "An Oceanographic Investigation Adjacent to Cay Sal Bank," Starr, ESSA TR, in press.
- "Some Current Measurements by Shallow Drogues in the Florida Current," F. Chew and G. A. Berberian, in press, Limnology and Oceanography.

(7011)

GULF STREAM STUDIES.

- (d) Field investigation; basic research.
- (e) Variations of the Gulf Stream were studied by means of oceanographic observations during 1965-67. Serial observations were made along a line across the stream off Charleston, S. C., and following the stream between Cape Hatteras and the Grand Banks. Purpose is to provide field data relevant to understanding dynamics of Gulf Stream variation.
- (g) Gulf Stream meandering east of Cape Hatteras is interpreted as quasi-geostrophic wave motion. The mean position is consistent with oscillation about a geostrophic contour, but amplitude and wavelength of meandering is not. It is concluded that instability is a more likely cause of meandering, but spatial rather than temporal growth is indicated.

(7012)

ESTUARINE CIRCULATION.

- (b) Jointly with M. Rattray, Jr., University of Washington, Seattle.
- (d) Theoretical; basic research.
- (e) Mathematical modeling of circulation and diffusion phenomena in estuaries. Purpose is to increase understanding of estuarine processes and to provide models to aid in interpretation of field studies and in development of techniques for prediction of circulation.
- (g) Similarity solutions have been obtained for equations and boundary conditions appropriate to an inlet in which circulation is induced by vertical mixing of an externally maintained density stratification such as has been reported for Baltimore harbor.

U. S. DEPARTMENT OF COMMERCE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION, WEATHER BUREAU, Silver Spring, Maryland 20910. Mr. William E. Hyatt, Associate Director of Weather Bureau (Hydrology).

(5664)

STREAMFLOW FORECASTING RESEARCH.

- (d) Theoretical and field; applied research.
- (e) In Silver Spring, Md., and at River Forecast Centers throughout the U. S., phenomena are being in-

- vestigated for improved objective forecasts of stream-flow. These phenomena include 1) storage and movement of rain and snowmelt through the soil, including the influence of evapotranspiration, and 2) routing of flow in natural channels.
- (g) An API-type hydrologic model was developed which provides continuous synthesis of stream flow. The model may be used operationally and/or serve as a standard for comparing conceptual hydrologic continuous models with conventional Weather Bureau forecasting procedure. All River Forecast Centers are equipped with computers or have computer capability and have adapted field procedures to digital computer operation.
- (h) "Continuous Hydrograph Synthesis with an API-Type Hydrologic Model," W. T. Sittner, C. E. Schauss and J. C. Monro, Water Resources Res., Vol. 5, No. 5, pp. 1007-1022, 1969.
- "An Operational System for Computer Preparation of Shortterm River Forecasts on the North Coast of California," R. J. C. Burnash and R. L. Ferral, IASH Symposium on "The Use of Analog and Digital Computers in Hydrology," Tucson, Ariz., Publication No. 80, Vol. 1, pp. 300-306, 1968.
- "Operational Streamflow Forecasting with the SSARR Model," V. P. Schermerhorn and D. W. Kuehl, IASH Symposium on "The Use of Analog and Digital Computers in Hydrology," Tucson, Ariz., Publication No. 80, Vol. 1, pp. 317-328, 1968.

(6154) HYDROMETEOROLOGICAL RESEARCH FOR DESIGN CRITERIA.

- (b) Several Federal agencies engaged in water management programs.
- (d) Largely theoretical; basic and applied.
- (e) Preparation of estimates of probable maximum precipitation, meteorological conditions for maximum snow accumulation and melting, hurricane wind fields, and rainfall intensity-frequency for design of spillways and other water-control structures and programs.
- (g) Detailed description and results are reported in the Water Resources Research Catalog.
- (h) "Rainfall Frequency Maps for Utah, Wyoming, Montana and Idaho," prepared by Special Studies Branch, Office of Hydrology, Weather Bureau, ESSA (Individual maps) 1970.
- "The Precipitation Regime of Long Island, New York," John F. Miller and R. H. Frederick, Geological Survey Professional Paper No. 627-A, 1969.
- "Hydrometeorological Studies," John F. Miller, to be published in the Proceedings of International Seminar for Hydrology Professors held at University of Illinois, July 13 to 25, 1969.
- "Probable Maximum Precipitation Over South Platte River, Colorado and Minnesota River, Minnesota," Hydrometeorological Report No. 44, 114 pages, January 1969.
- "Probable Maximum and TVA Precipitation for Tennessee River Basins up to 3000 Sq. Mi. in Area and Durations to 72 Hours," Hydrometeorological Report No. 45, 166 pages, May 1969.
- "Frequency and Areal Distributions of Tropical Storm Rainfall in the United States Coastal Region on the Gulf of Mexico," H. V. Goodyear, ESSA Technical Report WB-7, July 1968.
- "The Role of Persistence, Instability and Moisture in the Intense Rainstorms in Eastern Colorado, June 14-17, 1965," F. K. Schwarz, ESSA Tech. Memo. WBTM HYDRO 3, February 1967.
- "Meteorology of Major Storms in Western Colorado and Eastern Utah," R. L. Weaver, ESSA Tech. Memo. WBTM HYDRO 7, January 1968.
- "Probable Maximum Precipitation on the Lower Rio Grande," to be published in Proc. Amer. Water Resources Conf., October 27-30, 1969.

"Hydrometeorological Approach to the Assessment of the Frequency and Magnitude of Floods," Vance A. Myers. In "Assessment of the Magnitude and Frequency of Flood Flows," WMO Water Resources Series No. 30, 1967.

"Manual for Depth-Area-Duration Analysis of Storm Precipitation," V. A. Myers, et al., WMO No. 237TP129, 1969.

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U. S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, CRYOGENICS DIVISION, INSTITUTE FOR BASIC STANDARDS, Boulder, Colorado 80302. Dudley B. Chelton, Division Chief.

(7003)

CAVITATION SIMILARITY STUDIES.

- (b) National Aeronautics and Space Administration, Lewis Research Center.
- (c) Mr. Jesse Hord, Mechanical Engineer.
- (d) Experimental and theoretical; basic and applied research.
- (e) The purpose of this study is to extend the capability to design and predict the performance of liquid pumps and other liquid-handling components. The experimental program requires testing of five hydrodynamic bodies in liquid hydrogen and liquid nitrogen; desinent, incipient, and developed cavitation data are acquired. The data are then analyzed and correlation techniques are developed to account for scale size, geometry, fluid, fluid velocity, fluid temperature, etc.
- (g) Experiments are in progress. Accumulated experimental data and possible modifications to the Cavitation Similarity Theory have been reported.
- (h) "Incipient and Developed Cavitation in Liquid Cryogenes," D. K. Edmonds and J. Hord, NBS Tech. Note No. 374, February 1969.

(7004)

SLUSH HYDROGEN CHARACTERISTICS.

- (b) National Aeronautics and Space Administration, Marshall Space Flight Center.
- (c) Mr. Charles F. Sindt, Mechanical Engineer.
- (d) Experimental; applied research.
- (e) The purpose of this study was to acquire knowledge concerning the production, storage, and handling of slush hydrogen; slush hydrogen has great potential as a space vehicle propellant. This program required detailed analysis of solid particle size, texture and shape. Power and equipment requirements for efficient slush hydrogen production were determined. Slush flow characteristics, such as pressure drop in pipes, orifices and valves and pumping criteria were determined. Freshly produced mixtures of slush were upgraded to mass solid fraction of 0.54 while aged mass solid fractions as high as 0.63 were attained. Various techniques for sustaining a homogeneous-ly mixed slush were evaluated.
- (f) Completed.
- (g) Developed techniques for production and solid fraction upgrading of slush hydrogen. Establish criteria for determining the solid-fraction content of slush. Determined pump requirements and flow characteristics for slush hydrogen.
- (h) "Temperature-Entropy Diagram for Parahydrogen Triple-Point Region," C. F. Sindt and D. B. Mann, NBS Tech. Note No. 343, June 1966.
- "Liquid-Solid Mixtures of Hydrogen Near the Triple Point," D. B. Mann, P. R. Ludtke, C. F. Sindt, and D. B. Chelton, Advances in Cryogenic Engineering, Vol. 11, Proc. 1965 Cryogenic Engrg. Conf., K. D. Timmerhaus, Editor. Plenum Press,

New York, 1966.

"Quality Determination of Liquid-Solid Hydrogen Mixtures," D. E. Daney, D. B. Mann, Cryogenics 7, No. 5, October 1967.

"Slush Hydrogen Pumping Characteristics," D. E. Daney, P. R. Ludtke, D. B. Chelton, C. F. Sindt, NBS Tech. Note No. 364, April 1968.

"Slush Hydrogen Fluid Characterization of Instrumentation," C. F. Sindt, P. R. Ludtke, D. E. Daney, NBS Tech. Note No. 377, February 1969.

"Slush Hydrogen Flow Characterization and Solid Fraction Upgrading," C. F. Sindt, to be published in Advances in Cryogenic Engineering, Vol. 15.

England.

"Two-Phase (Liquid-Vapor), Mass Limiting Flow with Hydrogen and Nitrogen," J. A. Brennan, D. K. Edmonds and R. V. Smith, NBS Tech. Note No. 359, 1968; and Advances in Cryogenic Engineering, Vol. 14, Plenum Press, New York, 1969.

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U. S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, MECHANICS DIVISION, INSTITUTE FOR BASIC STANDARDS, Fluid Meters Section, Washington, D. C. 20234.
Fillmer W. Ruegg, Section Chief.

(7005)

CRYOGENIC FLOWMETERING.

(b) Automated Flow Systems.

(b) Naval Air Systems Command.

(c) Dr. David W. Baker, Research Engineer, NBS.

(d) Experimental; development.

(e) Methods and equipment for automatic testing and calibration of aircraft fuel system components are being investigated. At present, during the adjustment and calibration of gas turbine engine fuel controls, an operator manually sets input test parameters which remain stationary during a short time interval when test output data are manually recorded. In this program, the control of input parameters, compressor discharge pressure and test stand rpm, and the readout of control discharge flow rate, the test output, are all being automated. Emphasis is being placed on application of small, low-cost digital computer equipment, and on digital-oriented control and readout equipment to automate a conventional fuel control test stand installed at NBS. The immediate objective is to ascertain whether systems employing such digital equipment are technically feasible, and whether economies in test time and cost, and reliability consideration justify this approach.

(g) Design and construction of devices to interface the computer to instrument subsystems which read the input and output test parameters, and software programs to implement initial operation of these subsystems are complete. Normal calibration tests with the stand under computer control indicate adequate performance capability of the present prototype system.

(h) In preparation.

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U. S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, MECHANICS DIVISION, INSTITUTE FOR BASIC STANDARDS, Hydraulics Section, Washington, D. C. 20234.
Dr. G. Kulín, Section Chief.

(7007)

CRITICAL (CHOKING) TWO-PHASE FLOW.

(b) SNPO (NASA-AEC).

(c) Dr. R. V. Smith, Mechanical Engineer.

(d) Theoretical and experimental; doctoral thesis.

(e) Theoretical and experimental work was done to produce predictive expressions for two-phase, critical flow.

(f) Suspended.

(g) Results indicate that a theoretical model is successful for cases where the flow of the phases is characteristically separated and that choking or critical flow occurs essentially in the gas phase. This information is required for optimal design of a wide range of systems in power generation, petroleum and cryogenics.

(h) "Two-Phase, Two-Component, Critical Flow in a Venturi," R. V. Smith, Oxford University D. Phil. dissertation (1968) also with L. B. Cousins and G. F. Hewitt, Report (UK)AERE-R5736 Howell,

(g) An approximate theory is developed which applies only to the case of an unbounded fluid. However, it does not require the assumption of a low profile disturbance and also avoids anomalies found to be associated with a doublet disturbance. The nature of the disturbance and its effect upon the waves are embodied in a function, G , contained in the solution, which includes the doublet model as a special case. This function cannot exactly satisfy, nor be determined by, the condition of

(f) Completed.

(g) An approximate theory is developed which applies only to the case of an unbounded fluid. However, it does not require the assumption of a low profile disturbance and also avoids anomalies found to be associated with a doublet disturbance. The nature of the disturbance and its effect upon the waves are embodied in a function, G , contained in the solution, which includes the doublet model as a special case. This function cannot exactly satisfy, nor be determined by, the condition of

- no flow through the surface of the sphere. However, a suitable form of G is derived empirically from a part of the observations. The region of direct comparability between observations and theory is limited by the disparity in their outer boundary conditions. As far as comparison can be extended, the observations and theory are reasonably compatible.
- (h) "On Spheres and Doublets in Stratified Flow," Karl Lofquist, NBS Rept. No. 9987, 1968.
"Internal Waves Produced by Spheres Moving in Density Stratified Water," Karl Lofquist, NBS Rept. 10267, 1970.
- (5613)
RESPONSE OF A DENSITY-STRATIFIED LIQUID TO A SOURCE OR SINK IMPULSE.
(b) Office of Naval Research, Department of the Navy.
(c) Mr. Karl Lofquist, Physicist, NBS.
(d) Theoretical and experimental; basic research.
(e) A study of the internal waves produced by the sudden efflux or influx of liquid through a foam rubber hollow sphere simulating a "source" or "sink" situated within a linearly stratified liquid.
(g) Theory and experiments have been completed. Analysis is in progress.
- (5615)
INTERCOMPARISON OF TOWING TANK AND WATER TUNNEL CALIBRATIONS OF CURRENT METERS.
(d) Experimental; basic and applied research.
(e) Investigation of wall interference and turbulence effects on current meter calibrations in water tunnels. A 20-inch diameter open-circuit water tunnel is used in the experiments.
(h) Discussion by John L. French of "Are Individual Current-Meter Ratings Necessary?," J. Hyd. Div., ASCE, January 1969.
- (6013)
DAMPING OF SHALLOW-WAVES: SUMMARY OF AVAILABLE INFORMATION.
(b) Office of Naval Research, Department of the Navy.
(d) Analytical; basic research.
(e) A state-of-the-art review of viscous damping of waves, with analysis of available theoretical and experimental results.
- (7243)
MEASUREMENT OF LEE WAVE DRAG ON SPHERES.
(b) Office of Naval Research, Department of the Navy.
(c) Mr. Karl Lofquist, Physicist, NBS.
(d) Experimental and theoretical; basic research.
(e) Measurement of difference in drag between sphere moving in linearly stratified salt water and in fresh water.
- (7824)
SAND TRANSPORT BY WAVES.
(b) Coastal Engineering Research Center.
(c) Mr. Karl Lofquist, Physicist, NBS.
(d) Experimental and theoretical; basic research.
(e) Investigation of the effect of seepage flows, caused by passage of waves over a permeable bed, on the sand transport in the offshore zone.
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- U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, Division of Research, Denver Federal Center, Denver, Colorado 80225. Chief Engineer, Attention: 293.
- The following projects are reported in the Water Resources Research Catalog:
- (056W)
QUALITY OF WATER AS AFFECTED BY STRATIFIED FLOW.
Vol. 4, 5.0185.
- (057W)
INSTRUMENTATION, DATA ACQUISITION, AND COMPUTER TECHNIQUES.
Vol. 4, 7.0019.
- (058W)
FACTORS AFFECTING STABILITY OF ARTIFICIAL AND NATURAL CHANNELS.
Vol. 4, 8.0034.
- (059W)
FLOW SURFACE PROTECTION.
Vol. 4, 8.0038.
- (060W)
PIPELINE AND TUNNEL HYDRAULICS.
Vol. 4, 8.0042.
- (061W)
RADIOISOTOPE WATER FLOW MEASUREMENT IN HIGH-HEAD TURBINES AND PUMPS.
Vol. 4, 8.0065.
- (062W)
OPEN CHANNEL HYDRAULICS.
Vol. 4, 8.0127.
- (063W)
WATER MEASUREMENT.
Vol. 4, 8.0128.
- (065W)
GATES, VALVES, AND ORIFICES.
Vol. 4, 8.0037.
- (066W)
ENERGY DISSIPATORS.
Vol. 4, 8.0114.
- (3278)
CAVITATION OF CONCRETE SURFACE IRREGULARITIES.
(d) Experimental; applied research and design.
(e) Into-the-flow offsets with abrupt edges, chamfered edges, and rounded edges were tested to determine the velocity-head relationships for incipient cavitation.
(f) Inactive.
- (3612)
DISCHARGE COEFFICIENTS FOR RADIAL GATES.
(d) Experimental, laboratory and field investigations; applied research.
(e) Radial gates are used extensively in irrigation systems for discharge and water surface level control. Intelligent operation of the systems requires that the rate of flow passing the gated structure be known. Literature research resulted in an analytical approach and adjusted equation for the gate capacity with unsubmerged flow.
(f) Suspended.
(g) Analysis of model data for several USBR low-head radial gate installations resulted in design curves for determining discharge capacity. Curves are grouped according to number of gates.
(h) "Analysis of Discharge Data for Low-Head Radial Gates," D. L. King and T. J. Rhone, issue pending.
- (4794)
VERTICAL STILLING WELL.
(d) Applied research.
(e) A plexiglass model has been constructed to obtain optimum size and internal configuration of vertical

- stilling wells for high-head discharges. Promising designs will be further tested in a larger vertical stilling well model.
- (g) Optimum well dimensions will be determined for a range of wave heights in the downstream channel.
- (h) A report will be prepared.
- (4802)
STUDIES OF ORIFICES FOR AUTOMATIC RADIAL GATE CONTROLS.
- (d) Experimental; for design.
- (e) The studies are for the purpose of determining flow characteristics and discharge coefficients for various size orifices in floatwell intakes of automatic radial gate controls. A 1:1-scale model of a floatwell intake structure was constructed to determine discharge coefficients of the irregular orifice configuration in the regulating structure.
- (f) Completed.
- (g) Although the test arrangements differed substantially from arrangements for which data are presently available, measured coefficients compared closely with existing data.
- (h) "Studies of Orifices for Automatic Spillway Gate Controls," D. L. King, Rept. No. Hyd-596, Sept. 1969.
- (4959)
FLAT-BOTTOMED TRAPEZOIDAL VENTURI FLUMES.
- (d) Experimental; for design.
- (e) A pilot study of a single flume is being conducted to determine the best approach to a comprehensive program to generalize the design and calibration of this type of water measuring device.
- (f) Suspended.
- (g) The model study has demonstrated that the particular pilot flume tested is an adequate measuring device.
- (h) Report in preparation.
- (4960)
PROTOTYPE PIEZOMETRIC AND AIR DEMAND MEASUREMENTS OF 4- BY 4-FOOT TANDEM GATE - NAVAJO DAM, NEW MEXICO.
- (d) Field investigation.
- (e) To compare the model and prototype, piezometric measurements were obtained for the complete range of gate openings with a head of 164.5 feet. Prototype air demand measurements were made simultaneously with piezometric values to evaluate adequacy of the air supply system. Further tests are planned at heads of about 230 feet and 300 feet to more fully evaluate the hydraulic characteristics of this gate and to check the model scaling.
- (f) Investigation pending prototype measurements at higher heads.
- (5336)
BUTTERFLY VALVE STUDIES WITH CAVITATION OCCURRING.
- (d) Experimental; for design.
- (e) A commercial 8-inch, 125 psi butterfly valve is being tested under prototype head to determine the effects on cavitation characteristics, air demand, and discharge coefficients that result from discharging the valve directly into sudden enlargements, or through short conduits into the enlargements. Tests are made with and without the admission of air, and quantities of air needed to just quiet the cavitation are being obtained. Effects of air admission on the discharge coefficient are also being obtained.
- (f) Suspended.
- (g) Preliminary results show that satisfactory pressure reducing stations for high differential heads and low back pressures can be obtained with butterfly valves if the valves discharge directly into a 2.0 diameter enlargement. Air in sufficient quantities to relieve cavitation when the discharge enters the enlargement directly, or through short sections of pipe, has little effect upon the discharge coefficient.
- (h) Publication not anticipated in near future.
- (5338)
LABORATORY TESTS OF GATE SEALS UNDER PROTOTYPE HEADS.
- (d) Experimental; for design.
- (e) A facility for testing gate seals under heads of up to 600 feet was used on 16 specimens of seals having various combinations of fluoro-carbon and brass cladding bonded to the rubber. The tests included measuring the seal bulb extension and photographing and observing the general behavior of the seal under load during opening and closing cycles of the gate.
- (f) Completed.
- (g) Of the seals tested, the one best suited for high-head applications was of the clamp-on type having a fluoro-carbon cap extending over the bulb and both stems and a brass backing. This seal successfully withstood opening and closings cycles under heads of up to 600 feet.
- (h) "High-Head Gate Seal Studies," R. D. Mohrbacher, Rept. No. Hyd-582, March 1968.
- (5339)
MODEL-PROTOTYPE CORRELATION OF AIR DEMAND.
- (d) Theoretical and experimental; basic research, applied research.
- (e) The purpose of the studies is to develop criteria for the design of air vents in hydraulic structures. Basic parameters are being developed to describe the flow of air in a closed conduit partially filled with moving water. The results will be confirmed with prototype tests.
- (g) A general computer program has been written to predict the air flow through a vent connected to a penstock. The air flow is induced through a falling water surface within the penstock.
- (h) Publication anticipated in the near future.
- (5343)
STRATIFIED FLOW.
- (d) Experimental and theoretical; applied research.
- (e) A laboratory flume is being used to study the mechanism of selective withdrawal from stratified reservoirs. Temperature difference, monitored with thermistors, is being used to induce stratification.
- (g) A tentative theory for use in designing selective outlets and a computer program for its solution were developed and examined with experimental data.
- (h) "Hydraulics of Stratified Flow, Second Progress Report, Selective Withdrawal from Reservoirs," D. L. King, Report No. Hyd-595, September 1969.
- (5847)
CRYSTAL DAM OUTLET WORKS.
- (d) Experimental; design.
- (e) A 1:12-scale model was tested to evaluate the operation of the outlet works stilling basin. Two 3-foot, 3-inch square slide gates will discharge a maximum of about 2,000 cfs into the stilling basin under a head of approximately 200 feet.
- (f) Suspended.
- (g) The energy dissipating efficiency of the basin and the downstream flow conditions were investigated. Special attention was given to the measurement and analysis of hydrodynamic forces acting on various parts of the structure, particular-

- ly the cantilevered vertical concrete wall which separates the flow from the two gates.
- (5848)
EL VADO DAM OUTLET WORKS.
(d) Experimental; design.
(e) A 1:30-scale model was used to develop a flip bucket which would minimize river channel erosion by dispersing sizable releases, and would allow small releases to be bypassed through an offset opening in the right wall. The model contained a section of the dual gate controlled outlet works tunnel, the flip bucket, a section of the existing spillway, and a section of river channel.
(f) Completed.
(g) The recommended flip bucket contained two vertical confining walls and two sloping plane surfaces to intercept and direct the flow to the lip of the bucket. The best flow dispersion occurs for normal releases of from 2,000 to 4,000 cfs. Small releases are passed through an offset opening in the right wall.
(h) "Hydraulic Model Studies of the El Vado Outlet Works Flip Bucket," T. J. Isbester, Report No. Hyd-567, February 1968.
- (6306)
ANALYSIS OF PRESSURE FLUCTUATIONS IN STILLING BASINS.
(d) Experimental and field investigation; applied research.
(e) Frequency analyses were made of pressure fluctuations in a prototype stilling basin designed to dissipate the energy of flow from two hollow-jet valves. The basin was covered and the divider wall was thus supported at both top and bottom, providing the opportunity to measure the pressures without significant modification by flexure of the wall. Considerations were made for planning of the analog spectral analysis.
(g) The analysis showed that components with frequencies greater than 10 Hz are negligible. Nearly all of the energy occurs at frequencies less than 5 Hz. Maximum energy occurs at less than 2 Hz. Good agreement with data from hydraulic models was obtained.
(h) "Spectral Analysis, A Prototype Study," H. T. Falvey and D. L. King, ASCE Hydraulics Div. Cong., Logan, Utah, August 20-22, 1969.
- (6309)
IMPACT-TYPE STILLING BASINS.
(d) Experimental; applied research.
(e) Model studies were conducted on a 1.6- and 2.4-foot wide (48.76 and 73.15 cm), impact, USBR Type VI, stilling basins to modify and standardize existing procedures in the design of this basin.
(f) Completed.
(g) The basin dimensions in relation to discharge and velocity entering the basin and the amount, size, and location of riprap in the channel were standardized. The reduction in velocity and energy through the basin was determined.
(h) "Hydraulic Design of the Type IV (Impact) Stilling Basin," G. L. Beichley, Water Resources Tech. Publ., Research Rept. No. 24, 1970.
- (6310)
TEHAMA-COLUSA CANAL FISH CONCENTRATOR.
(b) Fish and Wildlife Service.
(d) Experimental; design.
(e) A 1:2.5-scale model was used to develop the design of the fish concentrator through which the fingerlings are to be concentrated from a discharge of 140 cfs into a discharge of 5 cfs flowing to an electronic counting device.
(f) Completed.
- (g) A fish concentrator was developed consisting of a sloping perforated plate screen 10 feet wide by 16 feet 3 inches long with adjustable orifices beneath the screen to control the flow through it to 135 cfs.
(h) Report in preparation.
- (6315)
DETERMINATION OF SEEPAGE BY ELECTRICAL LOGGING.
(d) Experimental; applied research.
(e) Tests were conducted in a laboratory seepage tank to study the application of electrical logging for locating and measuring seepage in canals. Tests were made with stationary and moving, non-polarizing calomel cell electrodes.
(f) Suspended.
(g) Large changes in seepage produced small but measurable changes in voltage between stationary calomel cells embedded in a sand bed on the bottom of the tank. Stationary electrodes suspended one-half inch above the seepage bed measured voltages of about one-tenth of those measured by cells in contact with the bed. Voltage readings from moving electrodes continually increased or decreased according to the direction of travel. The recorded voltage generally increased at a greater rate when there was seepage, but the slopes of the recorder trace could not be definitely related to canal seepage. The electrical logging method cannot yet be applied to measuring seepage from irrigation canals.
(h) "Laboratory Tank Studies of Electrical Canal Logging to Detect Seepage - Lower Cost Canal Lining Program," R. A. Dodge, Report No. Hyd-570, May 1968.
- (6316)
FARWELL MAIN CANAL - OPEN AND CLOSED CONDUIT SYSTEM PROGRAM.
(d) Experimental; applied research.
(e) Three tractive force test reaches were constructed on the Farwell Main Canal, Nebraska. Using the tractive force method, the test reaches were designed where one reach should erode, one reach remain stable, and another reach may have sediment deposits. Survey levels of the test reaches were taken over a period of 5 years to determine change of the canal cross-section through the reaches. A timber control check is located at the end of each reach. The control checks provide the proper hydraulic flow conditions for the test reaches and are used to measure canal discharge through the reaches. Hydraulic model tests were performed to determine the discharge calibration of three different shape trapezoidal weirs. The weir inverts were level with the upstream canal bottom. Tests were made for free and submerged flow conditions.
(f) Laboratory part completed.
(g) An electronic digital computer was used in analysis of test data and discharge computations. A least squares fit was made for the test data and a free-flow equation and submerged flow equation were obtained for each weir. Using the equations, discharge graphs and tables were made for each weir both for free and submerged flow.
(h) "Hydraulic Model Calibration and Computer Analysis of Trapezoidal Timber Control Check Weirs - Farwell Main Canal, Nebraska - OCCS Program," E. R. Zeigler, Rept. No. Hyd-583, Aug. 1968. Report in preparation for field work.
- (6317)
DRAINAGE FROM SLOPING IRRIGATED LAND.
(d) Experimental; applied research.
(e) A 60-foot long by 2-foot wide by 2-1/2-foot deep

- sand tank that can be tilted from 0 to 12 percent was constructed. One side of the tank has transparent plastic panels. Horizontal drains at right angles to the sand tank sides were placed at 6-foot intervals along the sand tank. The drains which simulate agricultural drains were 2 feet above the tank bottom. A sprinkler system distributes water evenly over the sand surface to simulate the application of irrigation water. Tests were made for 6-foot and 12-foot drain spacings at four different recharge rates and for sand tank slopes of 0, 2-1/2, 5, 7-1/2, and 10 percent slopes. Measurements of the ground-water table location and drain discharges were made. Dye tests to show flow lines were made at four different recharge rates and at a 2-1/2-percent slope. Pressure measurements at approximately 200 points between tile drains and the impermeable barrier were made from pressure taps installed in the plexiglass side for 12 test conditions.
- (g) Drain discharges for a given slope and recharge rate varied in the following manner. If the slope was steep enough there was no discharge from the first one or two drains at the upper end of the sand tank. The drain discharge increased progressively downslope for two or three drains. For the middle portion of the sand tank, the drain discharges were approximately the same. The drain discharge was equal to the amount of water applied between two operating drains. Photographs taken of the dye tests showed streamlines of water flow through the sand. Drawings showing lines of equal potential were obtained from the pressure data. For the sloping tests there was water passing beneath the drains and flowing down slope along the bottom of the sand tank.
- (h) Report in preparation.
- (6318)
PIPING OF BRINE BETWEEN EVAPORATORS IN A 2.5-MGD UNIVERSAL DESALINIZATION PLANT.
- (b) Office of Saline Water.
- (c) Mr. P. G. Tomalin, Office of Saline Water, Distillation Division, U. S. Dept. of the Interior, Washington, D. C. 20240.
- (d) Experimental; design.
- (e) A 1:2.33-scale model study was conducted to determine the driving force required to discharge a given quantity of 118°F, 5 percent salt saturated brine through the most critical of the interstage module piping and to develop design modifications as dictated by the results of the tests.
- (f) Completed.
- (g) Pipeline losses including entrance and exit losses exceed the available driving force between the last two modules and a loss coefficient curve for the system was determined for a range of Reynolds numbers.
- (h) Report in preparation.
- (6319)
MANIFOLD STUDIES FOR FLASH DISTILLATION DESALINATION PLANT.
- (b) Office of Saline Water.
- (c) Mr. P. G. Tomalin; see (6318) above.
- (d) Experimental; design.
- (f) Completed.
- (g) Tests have resulted in several flow-improving modifications.
- (h) "Hydraulic Model Studies of Pump Intake Manifold and Evaporation Trays, San Diego Saline Water Test Facility, Office of Saline Water," D. L. King, Rept. No. REC-OCE-69-3, November, 1969.
- (6320)
AIR VENT COMPUTATIONS - MORROW POINT DAM, COLORADO.
- (d) Applied research; basic research.
- (e) The development of a computer program to determine the magnitude of the reduced pressure in the intake gate chamber and the air flow rates through the vents during an emergency closure of the intake gate.
- (g) The program has been developed for the quasi-steady state condition. The effects of inertia are being investigated.
- (h) "Air Vent Computations; Morrow Point Dam; Colorado River Storage Project, Colorado," H. T. Falvey Report No. Hyd-585, 22 pages, July 1968.
- (6321)
DRAFT TUBE SURGE STUDIES.
- (d) Theoretical and experimental; basic and applied research.
- (e) Surging flow occurring in the draft tubes of Francis turbines causes rough operation and often produces power swings. The surging flow is produced by the phenomenon known as vortex breakdown, creating a stable unsteady flow condition. The purpose of the project is to investigate the basic nature of draft tube surging, to correlate model test and field test data, and to investigate the addition of appurtenances in the draft tube and changes in the draft tube geometry itself as a means of eliminating or reducing the magnitude and range of occurrence of the surging. An air model has been used in the laboratory study.
- (g) Surging occurs when the rate of flow of angular momentum reaches a critical value relative to the rate of flow of linear momentum. Surge frequency and peak-to-peak pressures can be correlated with a dimensionless momentum parameter for a particular draft tube geometry and are independent of viscous effects at high Reynolds numbers. Frequencies and pressures appear to be a function of the draft tube expansion angle and to some extent the length-to-diameter ratio. There is reasonable correlation with limited field test data and prototype model test data.
- (h) "Experimental Study and Analysis of Draft-Tube Surging," J. J. Cassidy, Rept. No. REC-OCE-69-5, October 1969.
- (6322)
GRAND COULEE DAM AND THIRD POWERPLANT.
- (d) Experimental; design.
- (e) Tests are being conducted on a 1:120-scale model of the Third Powerplant and all existing features at Grand Coulee Dam. Details of the forebay channel and tailrace of the plant, which will have an ultimate capacity of 7,200 mw from 12 units, are being investigated and modified where necessary.
- (g) The shapes of the forebay and tailrace channels for both a 6- and a 12-unit plant have been established. Velocities and water surface profiles have been determined. Tendencies for vortex formation at the penstock entrances were investigated.
- (6323)
GRAND COULEE THIRD POWERPLANT PENSTOCKS.
- (d) Experimental; for design.
- (e) A 1:41.75-scale model is being used to evaluate different entrances and elbows for the 40-foot diameter penstocks.
- (g) A penstock entrance that is much smaller and shorter than entrances designed by current criteria was found to have satisfactory flow and pressure conditions and a very small head loss coefficient. The tests also indicate that an accelerating elbow just upstream of the generator

entrance will be equally efficient with a curvature radius equal to either 2-1/2 or 3-1/2 times the penstock diameter.

(6324)

INTAKES, ENTRANCES, AND TRANSITIONS.

- (d) Experimental; for design.
- (e) Investigations are being performed to determine optimum configurations for intakes, entrances, and transitions for penstocks and outlet pipes. Tests will be made to determine the actual losses at entrances of different sizes and configuration. These tests will be extended to include studies of pressures and of vortex formation and to determine minimum submergence required to maintain adequate pressures and to prevent vortices.
- (g) Tests to date have indicated that penstock entrances can be greatly reduced in size with a minimum amount of streamlining without significantly increasing head losses or causing poor flow conditions.
- (h) "A New Look at Penstock Entrance Designs," A. J. Peterka and E. A. Lindholm, April 1968.

(6325)

CONCONULLY DAM SPILLWAY.

- (d) Experimental; for design.
- (e) A 1:18-scale sectional model is being used to develop a baffled chute as an energy dissipator for a 70-foot high spillway having a unit discharge of about 78 cfs per foot of width.
- (f) Completed.
- (g) The tests indicated that the baffled chute is very effective in preventing acceleration of the flow down the spillway. Tests are being continued to determine the erosion tendencies at the end of the chute.
- (h) Report in preparation.

(6328)

TIBER DAM AUXILIARY OUTLET WORKS.

- (d) Experimental; design.
- (e) A 1:17.53-scale model is being used to develop the design of a drop inlet from the existing canal outlet tunnel to the new auxiliary outlet.
- (f) Completed.
- (g) A curved deflector in the crown of the canal tunnel directly over the drop inlet has been developed to intercept the swirling motion of flow entering the drop inlet; and, thus, improve the flow pattern throughout the outlet tunnel downstream from the slide gate control.
- (h) Report in preparation.

(6329)

YELLOWTAIL DAM SPILLWAY REPAIRS.

- (d) Experimental; for design.
- (e) A model tunnel spillway has been constructed to study means of admitting air to the high velocity, open channel flow to cushion the forces of cavitation collapse thereby preventing damage to the concrete spillway surfaces.
- (f) Completed.
- (g) An aeration slot was designed which was hydraulically sound and admitted air around the entire jet just upstream from the bend.
- (h) Report in preparation.

(6330)

FOLSOM DAM SPILLWAY REPAIRS.

- (d) Experimental; for design.
- (e) A sectional model of the junction of Folsom Spillway and one outlet conduit was constructed and tested to determine a means of preventing cavitation damage to the spillway face when spillway releases are made.

(f) Completed.

- (g) An eyebrow was developed to deflect spillway flow away from the outlet conduit spillway junction eliminating cavitation conditions for spillway operation. A splitter pier to aerate the junction for simultaneous spillway outlet releases was abandoned because it would be extremely difficult to anchor to the spillway face.
- (h) Report in preparation.

(7014)

JACKSON LAKE DAM BAFFLE BLOCKS.

- (d) Experimental; design.
- (e) A 1:15-scale model was used to determine corrective measures needed to prevent additional erosion in the downstream channel. Two energy dissipator configurations were tested on the downstream apron. Several sluice operating arrangements were also tested.
- (f) Completed.
- (g) An end sill on the downstream apron yielded a slight improvement over the existing baffle block configuration in reducing downstream erosion. However, the improvement did not warrant a change in the existing configuration. Sluice operating arrangements proved to be a more effective means of reducing downstream erosion.
- (h) Report in preparation.

(7015)

UTE DAM OUTLET WORKS.

- (d) Experimental; for design.
- (e) A 1:8-scale model aided in the development of an enclosed basin type energy dissipator for a horizontal cylinder (fixed-cone) control valve discharging into a concrete-lined channel.
- (f) Completed.
- (g) An enclosed basin with flared walls and ceiling to intercept the cone-shaped jet followed by a 45° deflector on walls and ceiling with baffle blocks on floor was developed to contain the jet and dissipate the energy before allowing the flow to enter the channel.
- (h) "Hydraulic Model Studies of an Energy Dissipator for a Fixed-Cone Valve at the Ute Dam Outlet Works," G. L. Beichley, March 1970. (In press.)

(7016)

TOA VACA DAM SPILLWAY.

- (c) Rafael V. Urrutia, Executive Director, Puerto Rico Water Resources Authority, San Juan, P. R.
- (d) Experimental; for design.
- (e) A 1:48-scale model aided in the development of the hydraulic design of the radial gate-controlled open channel chute spillway with combination stilling basin and flip bucket.
- (f) Completed.
- (g) The combination stilling basin and flip bucket was modified along with the discharge channel to meet the design discharge requirements.
- (h) Report in preparation.

(7017)

WAHLUKE BRANCH CANAL LATERALS - BLOCK 25.

- (d) Experimental; for design.
- (e) A 1:6-scale model of one of the canal lateral turnouts aided in the design of the turnouts.
- (f) Completed.
- (g) A drop inlet through a grizzly in the floor of the canal was developed for use along with a constant-head orifice turnout to discharge the design flow from the canal in a satisfactory manner regardless of total main canal flow.
- (h) Report in preparation.

(7018)

MAIN CANAL BACON SIPHON AND TUNNEL.

- (d) Experimental; for design.
- (e) A 1:49.8-scale model was used to aid in developing the design of the entrance and exit canal transitions to the two siphons and to determine the size of the main canal and the design of the canal bifurcations both upstream and downstream of the siphons.
- (f) Completed.
- (g) Wave suppressors were developed for use with the two exit transitions to provide a smoother water surface and more uniform flow distribution in the canal downstream. Since one of the siphons was an existing structure, the two wave suppressors developed were not alike.
- (h) Report in preparation.

(7019)

FLOW AERATION DOWNSTREAM OF SLIDE GATES.

- (d) Experimental; for design.
- (e) A slide gate model is used to aid in the development of methods to induce air into the flow from existing slide gate installations and for general use in proposed new installations.
- (g) An offset away from the flow in the conduit floor and walls of the proposed outlets through Pueblo Dam was developed. Air supply slots in the walls together with a floor deflector to lift the jet from the floor at the gate frame was developed for the existing outlet works at Palisades Dam and the existing auxiliary outlet works at Navajo Dam.

(7020)

HORSE MESA DAM HYDRO-ELECTRIC EXPANSION.

- (b) Salt River Project.
- (c) Salt River Project, P. O. Box 1980, Phoenix, Arizona 85001.
- (d) Experimental; design.
- (e) A 1:24-scale model is being used to verify the hydraulic design of the intake-outlet structure for a new pump-turbine facility. Gradual expansion of the outflow from the penstock during the pump cycle and smooth flow into the penstock for generating flow were sought. Included in the model are the intake-outlet structure and the 15.5-foot diameter penstock down to the scrollcase.

(7021)

MORMON FLAT DAM HYDRO-ELECTRIC EXPANSION.

- (b) Salt River Project.
- (c) Salt River Project, P. O. Box 1980, Phoenix, Arizona 85001.
- (d) Experimental; design.
- (e) A 1:19-scale model was used to verify the hydraulic design of the intake-outlet structure for a new pump-turbine facility. Gradual expansion of the outflow from the penstock during the pumping cycle and smooth flow into the penstock for generating flow were sought. Included in the model are the intake-outlet structure and the 18-foot diameter penstock down to the scrollcase.
- (f) Completed.
- (g) The recommended intake-outlet structure is a diverging rectangular structure. The two side-walls diverged at an angle of $13^{\circ} 10'$. A pier along the centerline is open through the middle half of the structure. At the downstream end of the structure, short piers further divide the flow into four passages. A horizontal pier then connects the midpoints of the above vertical piers. The structure is of constant height through its full length.
- (h) Report in preparation.

(7022)

GRAND COULEE PUMP-TURBINE INTAKE AND TRANSITION.

- (d) Experimental; for modification.
- (e) Laboratory tests are being conducted to determine the modifications necessary to permit the Grand Coulee pump conduits to be used as turbine conduits. The pumpline siphon elbows, the conduit portals at the Banks Lake Canal headwall, and the location and configuration of trashracks are being investigated.

(7023)

TEHAMA-COLUSA CANAL SPAWNING BED VELOCITY AND OXYGEN MONITORING TESTS.

- (b) Fish and Wildlife Service.
- (d) Experimental; for design.
- (e) A sectional model is being used to develop a system for monitoring oxygen content and velocity of water flowing through salmon spawning gravel.
- (g) Tests are being made on a proposed system for measuring water velocity in salmon spawning gravels and measuring oxygen content from water samples. Salt water is injected into an upstream perforated pipe. Using a resistance bridge and recorder, the time for the salt cloud to travel between two sets of electrodes is measured from which the velocity in the gravel is determined. Oxygen content is measured by the polarographic method on samples pumped from imbedded perforated pipe.
- (h) Report will be prepared.

(7024)

RIPRAP STABILITY IN CHANNELS.

- (d) Experimental; applied research for Master's thesis.
- (e) A sectional model was used to measure critical velocity for beginning movement and velocity to cause a given depth of scour for riprap 1-1/2 to 9 inches in diameter. A new approach to control the scouring velocity was developed. A movable baffle gate was inserted into the open channel flow to cause a controlled velocity under the baffle gate and over the riprap bed.
- (f) Completed.
- (g) Velocity profiles were made between the bottom of the baffle gate and the riprap bed for the condition of (1) initial instability and (2) for scour to a depth equal to the largest size of riprap present in the particular test. Tests of different size groupings were made. Plots relating size and bottom velocity for conditions of initial scour and scour to the depth of one riprap particle thickness were made.
- (h) "Riprap Stability in Channels," John S. Watkins, M. S. thesis at Univ. of Colorado, Boulder, 1968.

(7025)

SUPPRESSED RECTANGULAR WEIR STUDY.

- (d) Experimental; applied research.
- (e) Laboratory studies were performed on a 4-foot wide weir box turnout structure for irrigation use with closed pipe inflow. The purpose of the study was to determine the shortest box and the best stilling baffle arrangement to produce a reasonably smooth water surface and uniform velocity profile upstream of a suppressed rectangular weir for discharges up to 10 cfs.
- (f) Completed.
- (g) The minimum length of the stilling box and a satisfactory baffle arrangement were determined which provided approach conditions that were suitable for establishing a rating curve for the weir up to about 12 cfs. The rating curve differs from accepted standard suppressed weir formulas because of the nonstandard approach conditions and method of measuring head. The Kindsvater-

Carter method has been used to fit an equation to the rating curve data.

(h) Report in preparation.

(7026)

PA MONG DAM SPILLWAY BUCKET ENERGY DISSIPATOR.

(d) Experimental; design.

(e) A 1:55-scale model was constructed to determine the optimum spillway bucket radius and tooth and spacing widths for the tailwater conditions at the Pa Mong damsite.

(f) Completed.

(g) A 13.5-meter radius stotted bucket resulted in the smoothest water surface conditions. A 21-meter long apron placed at bucket lip elevation produced very favorable ground roller action.

(h) Report in preparation.

(7027)

PUEBLO DAM SPILLWAY.

(d) Experimental; for design.

(e) A 1:56-scale model was used to study the free-fall spillway and plunge pool-type stilling basin for Pueblo Dam.

(f) Completed.

(g) The basin was designed to still a flood of 30,000 cfs (40-year flood) while the spillway was designed to pass 191,500 cfs. To minimize the magnitude of dynamic pressure on the floor of the plunge pool and improve the stilling action, the pool floor was lowered 9 feet.

(h) Report in preparation.

(7028)

AUBURN SPILLWAY GATE STUDY.

(d) Experimental; for design.

(e) A 1:24-scale sectional model was built to study conditions associated with the 11- by 17-foot upstream seal fixed-wheel gates for the spillways at Auburn Dam. The upstream seal concept was abandoned when heavy flow into the large gate slots could not be eliminated. The model is presently being modified to accommodate a downstream seal wheel gate.

(7029)

BUTTERFLY VALVE CONTROL USING AIR ACTUATED CYLINDER OPERATORS.

(d) Experimental; for design.

(e) Five 8-inch commercial butterfly valves are being tested to determine if satisfactory control of water can be achieved with air actuated cylinder operators. Use of air eliminates the need for providing drain facilities for waste resulting from valve actuation. Also, the valve seating capability is being tested after repeated openings and closings against pressures of up to 150 psi.

(7030)

CANAL AUTOMATION.

(d) Experimental development; applied research.

(e) Studies of a hydraulic filter designed by the University of California at Berkeley for the Bureau of Reclamation are in progress. The filter coupled to a comparator and communications equipment will be used as a downstream control for the automation of canal gates. Studies are also being made on the partial automation of canal turnouts used for delivery and measurement of water.

(g) Promising results were obtained in a field trial of the filter and communications system. Laboratory work is being performed to modify the system to correct difficulties encountered in the field test.

(7031)

DISCHARGE MEASUREMENTS USING RADIOISOTOPES IN HIGH-HEAD TURBINES AND PUMPS.

(b) Under contract for the U. S. Atomic Energy Commission.

(d) Experimental laboratory and field investigation; basic and applied research.

(e) The purpose of the project is to establish the feasibility of and develop procedures for making discharge measurements accurately, quickly, and with a minimum of personnel and equipment. One of the goals of the program is to develop the method to a precision that would allow discharge measurements to be made to a probable inaccuracy of $\pm 3/4$ of 1 percent.

(g) Field measurements in the fifth of five phases of the project have been completed. Reporting of these results and writing a procedures manual showing the limitations of the method are in progress.

(h) Reports by the Bureau to the AEC: "Discharge Measurements Using Radioisotopes in High Head Turbines and Pumps," USAEC Rept. No. TID23737, Sept. 1966; "Discharge Measurements Using Radioisotopes in High Head Turbines and Pumps at Flatiron Power and Pumping Plant," USAEC Rept. No. TID25177, Dec. 1968; and "Discharge Measurements Using the Radioisotope Velocity, Integrated Sample, Dilution, and Total-Count Methods at Flatiron Power and Pumping Plant," USAEC Rept. No. TID25185, July 1969.

(7032)

REAERATION OF STREAMS AND RESERVOIRS.

(d) Experimental and theoretical; applied research.

(e) A literature search is being conducted which will result in a state-of-the-art report and a definition of research needs. Emphasis will be placed on development of equipment and methods for reaeration of large volumes of water.

(7033)

STRUCTURES FOR IMPROVED RIVER DISCHARGE MEASUREMENT AND MIXING OF POLLUTANTS.

(d) Experimental; design.

(e) Incomplete mixing of pollutants, particularly salinity, and the shifting bed of the Colorado River at the Northern International Boundary with Mexico, make accurate measurement of water quality and quantity very difficult.

(g) Hydraulic models have been used to determine (1) the configuration of a horizontal flume which may include an acoustic velocity meter for improved discharge measurement and (2) the shapes and locations of solid baffles in the channel to promote mixing of pollutants and eliminate expensive multi-point sampling procedures.

(h) "Colorado Front Work and Levee System, Hydraulic Model Studies for Development of Mixing and Rating Structures, Delivery of Water to Mexico," D. L. King, Rept. No. REC-OCE-70-8, January 1970.

(7034)

PUEBLO FISH HATCHERY OUTLET WORKS.

(d) Experimental; design.

(e) Design of selective outlets for the water supply of a proposed fish hatchery at Pueblo Dam requires a knowledge of the reservoir temperature distribution, the effects of an existing barrier dam, and operation of the river outlets.

(g) A 1:60 hydraulic model has been used to determine the effects of the barrier dam and operation of the river outlets. Stratification patterns simulated in the hydraulic model were determined by a mathematical prediction model. Optimum locations

for the hatchery outlets have been determined. The advisability of removing the barrier dam is being investigated.

(7035)

AUBURN DAM SPILLWAYS.

- (d) Experimental; design.
- (e) A 1:72 model is used to study flow conditions in the chutes, stilling basins, and river channel. The service spillway is located on the left abutment and discharges into a hydraulic jump stilling basin. The emergency spillway on the right abutment terminates in a flip bucket. Each spillway discharges up to 160,000 cfs through controlled orifices located up to 150 feet below the maximum water surface. The model is also being used to determine optimum sequencing of the orifices.
- (g) A hump has been recommended for the service spillway chute to improve the distribution of flow entering the stilling basin. The emergency spillway flip bucket is being modified to direct the flow away from the right bank of the channel.

(7036)

SILVERJACK DAM SPILLWAY.

- (d) Experimental; design.
- (e) A landslide during construction of the spillway stilling basin resulted in relocation of the basin and, in turn, required a horizontal curve in the spillway tunnel. Also, the new basin depth was shallower than that required for a stable hydraulic jump. A hydraulic model was constructed to determine flow conditions for the modified design.
- (f) Completed.
- (g) Guide vanes were developed for the tunnel to improve the distribution of flow entering the stilling basin. Large hooked baffle blocks were developed to stabilize the hydraulic jump.
- (h) "Hydraulic Model Studies of Silverjack Dam Spillway Stilling Basin," T. J. Rhone, Report No. REC-OCE-70-3.

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U. S. DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY,
Water Resources Division, Washington, D. C. 20242.
E. L. Hendricks, Chief Hydrologist.

(2950)

SEDIMENT TRANSPORT AND CHANNEL ROUGHNESS IN NATURAL AND ARTIFICIAL CHANNELS.

- (c) Mr. Thomas Maddock, Jr., U. S. Geological Survey, Tucson, Arizona.
- (d) Basic research.
- (e) Field and laboratory studies, original and other investigations will be analyzed in terms of sediment movement, channel roughness, shear distribution in channel prism and other effects on shape of natural channels.
- (g) Relations between velocity and sediment load have been developed. Relations involving slope are shown to be indeterminate within certain limits.
- (h) "The Behavior of Straight Alluvial Channels," U. S. Geol. Survey Prof. Paper in stage of final review.

(4787)

TRANSPORT PROCESSES IN FLUID FLOWS.

- (c) Dr. Akio Ogata, U. S. Geological Survey, P. O. Box 657, Honolulu, Hawaii.
- (d) Experimental and theoretical study; basic research.
- (e) Theoretical and laboratory study of microscopic and macroscopic aspects of flow through porous media.

(5075)

DOPPLER VELOCITY METER.

- (c) Mr. G. F. Smoot.
- (d) Experimental; instrument development.
- (e) The objective is to measure the instantaneous local velocity by means of the Doppler frequency shift of an ultrasonic signal reflected by minute particles of suspended sediment.
- (g) Models undergoing laboratory and field tests.

(5604)

MECHANICS OF FLUID RESISTANCE.

- (c) Dr. H. J. Tracy, U. S. Geological Survey, WRD, 900 Peach Tree Street, N. E., Atlanta, Georgia 30323.
- (d) Theoretical and laboratory investigation; basic research.
- (e) The objective of this study is to attempt to describe the effects of the boundary on fluid resistance in terms of dimensionless ratios characterizing the physical size and shape of the roughness.
- (g) The experimental aspect of the work is being conducted in an artificially roughened, closed circular, air tunnel using hot-wire anemometer equipment to determine velocity profiles, turbulence, and energy spectra. The work consists of tests in which roughness element size, density of spacing, and shape are systematically varied. The resulting turbulence spectra are being analyzed in order to correlate the physical dimensions of the roughness with the energy and momentum transfer mechanisms in turbulent flow.

(5606)

MULTIPLE CHANNEL DIGITAL RECORDING SYSTEM.

- (c) Mr. G. F. Smoot.
- (d) Instrument development.
- (e) The objective of this project is to develop a reliable, battery powered, sensing instrument for field operation which is capable of positioning a punched paper-tape digital recorder. The instrument would be used to provide a variety of hydrologic parameters in rapid sequence for recording on tape.
- (g) A transistorized system incorporating an A-C Wheatstone bridge balanced by a D-C servo system of minimum power requirements has been developed and is undergoing field testing.
- (h) "New Instrumentation for Watershed Investigations," G. F. Smoot, Proc. Symp. on Experimental and Representative Areas, Intl. Assoc. Scientific Hydrology, 1965.

(5607)

EVALUATION OF DEPENDENT AND INDEPENDENT VARIABLES IN OPEN CHANNEL FLOW.

- (c) C. F. Nordin, U. S. Geol. Survey, ERC, CSU Foot-hills, Fort Collins, Colorado 80521.
- (d) Experimental; basic research.
- (e) The objective is to identify and evaluate the dependency characteristics of flow and sediment measures of alluvial channel flow. The experiments are designed to (1) determine mean flow parameters and channel adjustments when bed material is an independent variable; (2) determine the importance of depth as a scale parameter and as a driving force; (3) determine the time for change when an independent variable is changed; (4) determine the variance of slope, depth, velocity, sediment transport, and bed conditions in time and space.
- (g) The series of unique experiments with single radioactive particles of high activity showed that the particle step lengths were gamma distributed, the particle rest periods followed the exponential

- distribution, and the parameters of the distributions were related to flow conditions. The bed form lengths were gamma distributed with the relation most evident for the dune bed forms. Observations during the experiments suggested that most deposition and erosion occur below the mean bed elevation.
- (h) "Statistical Properties of Dune Profiles," C. F. Nordin, Jr., Ph.D. Dissertation, Colo. State Univ., Fort Collins, Colo. 1968.
 "Statistical Description of Sand Waves from Stream-bed Profiles," C. F. Nordin, Jr., and E. V. Richardson, Int. Assoc. Sci. Hydrol. Bull., Vol. 13, No. 2, 1968, p. 69-84.
 "Some Applications of Cross-Spectral Analysis in Hydrology: Rainfall and Runoff," I. Rodriguez-Iturbe and C. F. Nordin, Jr., Water Resources Research, Vol. 5, No. 3, p. 608-621.
 "Motion of Single Particles in Sand Channels," N. S. Grigg, Ph.D. Dissertation, Colo. State Univ., Fort Collins, Colo. 1969.
 "The Behavior of Large Particles Falling in Quiescent Liquids," G. E. Stringham, D. B. Simons, and H. P. Guy, U. S. Geol. Survey Prof. Paper 562-C, 1969, 36 p.
 "Response of a Laboratory Alluvial Channel to Changes of Hydraulic and Sediment-Transport Variables," R. E. Rathbun, H. P. Guy, and E. V. Richardson, U. S. Geol. Survey Prof. Paper 562-D, 1969, 32 p.
- (5610)
 MECHANICS OF FLOW STRUCTURE AND FLUID RESISTANCE - MOVABLE BOUNDARY.
 (c) R. S. McQuivey, U. S. Geol. Survey, Engrg. Res. Ctr., Foothills Campus, Colo. State Univ., Fort Collins, Colorado 80521.
 (d) Experimental, theoretical and field investigation; basic research.
 (e) The objective is to measure the internal flow field of turbulent shear flow in an open channel in order to obtain a fundamental understanding of the mechanics of fluid resistance. Further knowledge of the mechanics of flow structure will give a better understanding of the phenomena of energy dissipation, velocity distribution, shear distribution and the transport and dispersion of solutes and sediment.
 (g) Turbulence characteristics were obtained with the hot-film anemometer in the 8-foot wide flume over an alluvial boundary, the Rio Grande conveyance channel, the Columbia River, the Missouri River, and the Mississippi River. Point sediment samples were collected at the point where the turbulence measurements were taken. The analysis of this data has been completed and interpretation of the data is continuing.
 (h) "Turbulence in a Hydrodynamically-Rough and Smooth Open-Channel Flow," R. S. McQuivey, Ph.D. Dissertation, Colo. State Univ., Fort Collins, Colo., 1967.
 "Comparison Between Hot-Film and Hot-Wire Measurements of Turbulence," E. V. Richardson, R. S. McQuivey, V. A. Sandborn, and P. M. Jog, Proc. 10th Midwestern Mech. Conf., Colo. State Univ., Fort Collins, Colo., 1967.
 "Measurement of Turbulence in Water," E. V. Richardson and R. S. McQuivey, ASCE Hyd. Div. Jour., Vol. 94, No. HY2, 1968, p. 411-430.
 "Some Turbulence Characteristics in Open-Channel Flow," R. S. McQuivey and E. V. Richardson, ASCE Hyd. Div. Jour., Vol. 95, No. HY1, 1969, p. 209-224.
 "Rotary Flow Meter as Turbulence Transducer," E. J. Plate and J. P. Bennett, ASCE Eng. Mech. Div. Jour., Vol. 95, No. EM6, 1969, p. 1307-1329.
 "Open Channel Flow Turbulence Measurements With a Propeller Flow Meter and a Hot-Film Anemometer," J. P. Bennett and R. S. McQuivey, U. S. Geol. Survey Prof. Paper 700-B, 1970.
- (5839)
 MECHANICS OF GROUND-WATER FLOW.
 (c) Mr. H. H. Cooper, Jr.
 (d) Theoretical investigations with field applications; basic and applied research.
 (e) Analysis of ground-water flow problems for which practical need has developed out of field investigations or other sources.
 (g) (1) A solution for the response of well-aquifer systems to seismic waves as a function of well geometry, aquifer constants, and frequency of seismic wave was derived and checked by an electric analog model. (2) A technique for determining the rate of ground-water flow through semi-confining beds from the earth's thermal profile was devised. (3) Solutions for the nonsteady radial flow toward a well pumping from (a) an infinite two-layered aquifer, and (b) an infinite anisotropic aquifer were derived.
 (h) "Rates of Vertical Groundwater Movement Estimated from the Earth's Thermal Profile," J. D. Bredehoeft and I. S. Papadopoulos, Water Resources Res., Vol. 1, No. 2, pp. 325-328, 1965.
 "Seismic Fluctuations in an Open Artesian Water Well," J. D. Bredehoeft, H. H. Cooper, Jr., I. S. Papadopoulos and R. R. Bennett. USGS Prof. Paper 525-C, pp. C51-57, 1965.
 "The Response of Well-Aquifer Systems to Seismic Waves," H. H. Cooper, Jr., J. D. Bredehoeft, I. S. Papadopoulos and R. R. Bennett. J. Geophys. Res., Vol. 70, No. 16, pp. 3915-3926, 1965.
- (5841)
 DENVER MULTIPHASE FLOW.
 (c) E. P. Weeks, U. S. Geol. Surv., Denver Federal Ctr., Denver, Colo. 80225.
 (d) Theoretical and field investigation.
 (e) Devise and test methods of measuring flow in, and hydraulic properties of, the unsaturated zone in the field. Measure velocities of fluids underground by analysis of temperature profiles. Develop and test methods of predicting the nature of flow in the unsaturated zone. Improve, and develop new techniques for field measurement of evapotranspiration.
 (g) Measurement of the time lag and attenuation of fluctuations in gas pressure due to barometric changes as functions of depth below the land surface were made in the unsaturated zone near Cuba, New Mexico, for determining permeability of the unsaturated zone.
 Although the field tests were successful, improvement in the instrumentation adopted is indicated. Type curves for analyzing drawdowns observed in well fields having variable discharges at scattered locations were developed for the New Mexico ground-water district through the Geological Survey Computations Unit. The computer program evolved is available for calculating the hydraulic properties of aquifers in areas where intensive use of ground-water is monitored at observation wells. Underground temperature profiles were observed in the field near Globe, Arizona and Roswell, New Mexico to test the possibility of using the temperature profile for indicating vertical velocities of ground water through beds having low permeability. Indications are that vertical velocities as small as 0.1 foot per year can be identified by analysis of the steady-state temperature profile observed in beds about 100 feet or more in thickness.
 The relation between losses from ground water and

- evapotranspiration is being studied with the aid of the field offices of the Water Resources Division, U. S. Geological Survey, in Colorado. Measurements of ground-water levels, soil moisture tension and content, and temperature are being made at four 25 acre sites in the Arkansas River Valley. Lateral contribution to ground-water loss, due to spatial changes in flow through the aquifer, is monitored by finite-difference analysis of the shape of the water table. Project interest lies in testing of field techniques of measuring the hydraulic properties of the unsaturated zone, and defining the relation between evapotranspiration and depth to the water table. Field installations were completed in May 1965, and rebuilt by October 1965 after destruction by floods.
- (h) "Effects of Water Table Conditions on Water Level Changes Near Pumping Wells," R. W. Stallman, Water Resources Res., Vol. 1, No. 2, p.295-312, 1965.
- "Steady One-Dimensional Fluid Flow in a Semi-infinite Porous Medium With Sinusoidal Surface Temperature," R. W. Stallman, J. Geophys. Res. Vol. 70, No. 12, p. 2821-2827, 1965.
- (5842)
THE MOVEMENT OF RADIONUCLIDES IN THE COLUMBIA RIVER ESTUARY.
- (b) U. S. Atomic Energy Commission.
- (c) Mr. D. W. Hubbell, Project Chief, U. S. Geol. Surv., P. O. Box 3202, Portland, Oregon 97208.
- (d) Experimental and theoretical; applied research.
- (e) Certain radionuclides enter the Columbia River from the Hanford installation of the U. S. Atomic Energy Commission. Part of the radionuclides remain in solution, part are sorbed by fluvial sediments, and part are sorbed by biota. In order to insure that no dangerous condition prevails or develops in the Columbia River estuary, it is important to know the distribution of radionuclides in time and space, and the processes by which the distribution is altered. The purpose of this investigation is to study the movement of radionuclides in the Columbia River estuary as it is affected by flow, sediment transport, and chemical processes; to assess the distribution of radioactivity in the estuary; to develop measurement methods and techniques for large estuaries; and to contribute knowledge of estuarine processes.
- (g) Measurement equipment and techniques have been developed for collecting necessary data in the estuary. The equipment includes systems for measuring water discharge rapidly, for collecting large-volume water and suspended-sediment samples, for filtering large-volume samples rapidly, for collecting 6-foot long bed-material cores, and for monitoring radioactivity in situ. The areal distribution of radioactivity in the estuary varies markedly and, in general, high activities are associated with fine sediments.
- (h) "A Sampler for Coring in Rivers and Estuaries," E. A. Prych and D. W. Hubbell, Bull. Geol. Soc. Amer.
- "Measurement Equipment and Techniques Used in Studying Radionuclide Movement in the Columbia River Estuary," E. A. Prych, D. W. Hubbell and J. L. Glenn, Proc. ASCE Coastal Engrg. Conf., 1966.
- (5843)
SEDIMENT TRANSPORT AND TIDAL FLOW HYDRAULICS.
- (b) U. S. Geological Survey.
- (c) Mr. W. L. Haushild, Project Chief, U. S. Geol. Surv., P. O. Box 3202, Portland, Oregon 97208.
- (d) Field investigation; applied research.
- (e) Small amounts of minerals in the water used for cooling the reactors at the Hanford installation near Richland, Wash., are activated and subsequently discharged into the Columbia River in the controlled release of the cooling water. The purpose of the project is to determine the disposition of these radionuclides in and along the channel and the mechanics of transport of the radionuclides by the water and sediment in the river. The investigation is intended to supply information from the 330-mile reach of the Columbia River between Hanford and the head of the estuary.
- (g) The transport and retention of radionuclides correlates with (1) the flow characteristics of the river system, and (2) the influence of the chemical and physical composition of the environment system. The radionuclides affixed to the sediments varies for specific radionuclides and correlates with the physical and mineral characteristics of the sediments. There is a differential transport of these affixed radionuclides because of the differences in the fall velocity of the sediments, and this difference in transport affects the retention of radionuclides in the study reach. The digital computer solutions of a mathematical model for transient river flow have been successfully applied to the production of continuous discharge data for tidal-affected flows of the Columbia River at Vancouver, Wash.
- (h) "Concurrent Collection of Hydraulic and Sediment Data in Rivers," G. R. Dempster, Jr. and H. H. Stevens, Jr., Jour., Am. Water Works Assoc., Vol. 57, No. 9, pp. 1133-1138, Sept. 1965.
- (6069)
GRAIN SIZE DISTRIBUTION AND BEDLOAD TRANSPORT.
- (c) G. P. Williams.
- (d) Basic research.
- (e) Experimental flume studies relating bedload transport rate to various channel factors, and especially variations resulting from changes in size distribution keeping median grain size constant.
- (h) "Flume Experiments on the Transport of a Coarse Sand," U. S. Geol. Survey Prof. Paper 562-B, Sept. 1967.
- (6070)
HYDRAULIC STUDIES OF OVERLAND FLOW.
- (c) W. W. Emmett.
- (d) Basic research; field study.
- (e) Determine magnitude and evaluate effectiveness of hydraulic characteristics of overland flow as a landscaping agent and its role in the hydrologic cycle.
- (6071)
REAERATION IN OPEN CHANNEL FLOW.
- (c) R. E. Rathbun, U. S. Geological Survey, ERC, CSU Foothills, Fort Collins, Colorado 80521.
- (d) Experimental; basic research.
- (e) Investigation of processes by which dissolved oxygen is assimilated by flowing water in an open channel, and to develop improved criteria for predicting rate of assimilation as a function of flow, channel, and other measurable environmental characteristics.
- (g) A consideration of the temperature dependence of the reaeration coefficient showed that all previously reported experimental values of the temperature coefficient lie between the theoretical temperature coefficient values for the two limiting forms of the film-penetration model of Dobbins.
- (h) Discussion of "Effects of Temperature on Stream Aeration," Ivan Metzger, R. E. Rathbun and J. P. Bennett, ASCE Sanitary Eng. Div. Jour., Vol. 95, No. SA5, 1969, p. 985-988.

(6654)

WATER LANDING IMPACT OF SPACECRAFT AND AIRCRAFT.

- (b) NASA and other Government agencies.
- (c) Head, Impacting Structures Section, Mr. Lloyd J. Fisher, Mail Stop 347.
- (d) Experimental and analytical applied research.
- (e) Experimental landing impact investigations are made with scaled dynamic models. Various landing attitudes, speeds, and body configurations are simulated. Hydrodynamic force and pressure distribution data on either relatively rigid or partially elastic models are obtained for comparison with theory. Specific energy dissipation capabilities are determined for various impact systems and materials using structural testing procedures and drop model techniques.
- (h) "Effects of Heat Shield Structure Flexibility on Water Landing Loads of Apollo Spacecraft Models," Sandy M. Stubbs and Melvin E. Hathaway, NASA TN D-5108, March 1969.
"Water Pressures and Accelerations Encountered During Landing of a Dynamic Model of the Apollo Spacecraft with a Deployed-Heat-Shield Impact Attenuation System," Sandy M. Stubbs, NASA TN-4275, March 1968.
Publications may be obtained from the Scientific and Technical Information Division, NASA, Washington, D. C. 20546.

(7037)

HELIUM INJECTION TO REDUCE RESONANT FREQUENCIES IN PROPELLANT LINES.

- (c) Mr. Brantley R. Hanks, Mail Stop 230.
- (d) Experimental, applied research.
- (e) Study injection of helium bubbles into flowing liquid to reduce resonant frequencies of propellant lines in simulated flight acceleration field.
- (f) Completed.
- (g) Injection of helium bubbles into a flowing liquid increases the compressibility of the fluid and hence lowers the resonant frequencies of all modes. Response pressure at resonance is reduced in the same proportions as frequencies and both effects are changed very little by manned-flight acceleration levels. This method can be used to move propellant line frequencies away from structural resonances provided higher propellant line modes are not lowered into an undesirable range.
- (h) "Helium Injection to Reduce Resonant Frequencies in Propellant Lines," Brantley R. Hanks and David G. Stephens, J. Spacecraft and Rockets, Vol. 6, No. 10, pp. 1202-1204, October 1969.

(7038)

THE BEHAVIOR OF LIQUID SQUEEZE-FILMS SUBJECTED TO VIBRATING LOADS.

- (c) Mr. Brantley R. Hanks, Mail Stop 230.
- (d) Experimental and analytical, applied research.
- (e) Study the use of liquid squeeze-films to attach objects to vibrating bases in normal and low pressure environments.
- (f) Completed.
- (g) Liquid squeeze-films are capable of bonding objects to bases vibrating at very high acceleration levels normal to the film plane provided the frequency of vibration is above some minimum value. This minimum frequency is a function of film geometry and liquid viscosity and the bonding force is determined by the liquid cavitation pressure. Under the short oscillatory loading periods, liquid tension is quite evident and con-

siderable bonding force can be obtained in vacuum environments.

- (h) "The Use of Liquid Squeeze-Films to Support Vibrating Loads," Brantley R. Hanks, The Shock and Vibration Bulletin, No. 39, Part 2, pp. 77-86, February 1969.

(7039)

STUDY OF FLEXIBLE ANTI-SLOSH BAFFLES.

- (c) Head, Environmental Systems Section, Mr. David G. Stephens, Mail Stop 230.
- (d) Experimental, applied research.
- (e) Determine performance characteristics of flexible anti-slosh baffles as compared to geometrically similar rigid baffles in large-scale tests.
- (f) Completed.
- (g) Flexible, lightweight, anti-slosh baffles can be more effective for preventing fuel slosh than rigid baffles. Their performance is related to a flexibility parameter which aids in scaling and optimizing baffle configuration. On a payload weight basis, the savings realized by using flexible anti-slosh baffles can be great.
- (h) "Flexible Baffles for Slosh Damping," David G. Stephens, J. Spacecraft and Rockets, Vol. 3, 1966.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, Lewis Research Center, 21000 Brookpark Road, Cleveland, Ohio 44135. Bruce T. Lundin, Director.

(6336)

STUDY OF OUTFLOW RESIDUALS FOR INTERCONNECTED SPHERICAL TANKS.

- (c) Robert J. Boyle, Aerospace Engineer.
- (d) Theoretical and experimental applied research.
- (e) The project consists of a study of the liquid residuals in a set of interconnected spherical propellant tanks having individual outflow lines flowing into a common line. Liquid residuals are affected by total outflow rate, initial mass imbalance in tanks, differences in outflow line characteristics, size of tank interconnect lines, and for a flight vehicle, the vehicle acceleration history during outflow.
- (f) Completed.
- (g) Results of one-dimensional, incompressible flow analysis agreed well with experimental tests outflowing water from multiple interconnected tanks.
- (h) "Analytical and Experimental Investigation of Outflow Residual in Interconnected Spherical Tanks," Harold J. Kasper, Robert J. Boyle, NASA TN D-4828, Sept. 1968. (Available from NASA Scientific and Technical Information Facility, College Park, Maryland.)

(6337)

ATLAS LAUNCH VEHICLE FEED SYSTEM DYNAMICS.

- (c) Carl F. Lorenzo, Aerospace Engineer.
- (d) Theoretical and experimental applied research.
- (e) Study is to demonstrate the ability to predict the behavior of the complex feedline system for a full-scale vehicle. The line flows water with vibration inputs to the vehicle. Termination impedances have been simulated. A similar study is being made to obtain a simple, but more accurate, method of predicting feedline inlet pressure in longitudinally oscillated thin wall tanks. Small scale experimental tank is being used to evaluate proposed methods.
- (f) Completed.
- (g) Acceleration responses obtained to force input over a frequency range from 1 to 120 Hertz. Results indicated that a one-dimensional model may not be sufficient to predict vehicle dynamic

- characteristics.
- (h) "Experimental Longitudinal Dynamics of an Empty Stub D Atlas Vehicle," William G. Costakis, Carl F. Lorenzo, NASA TM X-1682, November 1968. (Available from NASA Scientific and Technical Information Facility, College Park, Maryland.)
- (6342)
LIQUEFIED-GAS FLOW MEASUREMENT.
- (c) Isidore Warshawsky, Chief, Instrument Research Branch.
- (d) Experimental basic research.
- (e) The program consists of development, test, and evaluation of techniques and equipment for accurately measuring the flow of liquefied gases. Precise measurement of flow is essential in most research and development programs.
- (h) A NASA report on performance parameters of turbine-type flowmeters in liquid hydrogen, TN D-3770, was published.
- (6344)
HYDRODYNAMIC JOURNAL BEARING PERFORMANCE IN WATER AND LIQUID SODIUM.
- (c) William J. Anderson, MS 23-2.
- (d) Experimental and theoretical applied research.
- (e) Investigations of the stability characteristics of tilting pad, herringbone, lobed and stepped journal bearing configurations are being carried out. Analyses of lobed and stepped bearings are being made and experiments are being conducted with all of these bearing types in water at high speeds and low loads.
- (g) Stability experiments with 1.5-inch diameter herringbone grooved and three-sector journal bearings have been conducted in water at zero applied load and speeds to 12,000 rpm. The use of water at 80°F gave results similar to those obtained with liquid sodium at 800°F, and allowed a great simplification of the experimental procedure. The herringbone grooved bearings had a smaller range of stable operation than predicted by laminar, small eccentricity theory, but were far superior to a 100° partial arc bearing. Three sector bearings, with each sector tilted to produce a wholly converging film, were more stable than herringbone grooved bearings. Analyses of Rayleigh step journal bearings showed that these bearings can also inhibit instability.
- (h) "Experiments with Hydrodynamic Journal Bearings of Various Materials and Designs in Sodium at Temperatures to 800°F," Fredrick T. Schuller, William J. Anderson, and Zoltan Nemeth, ASLE Trans., Vol. 11, pp. 140-154, 1968. "Experiments on the Stability of Water Lubricated Herringbone-Groove Journal Bearings, I - Theoretical Considerations and Clearance Effects" and II - Effects of Configuration and Groove to Ridge Clearance Ratio," Fredrick T. Schuller, David P. Fleming, and William J. Anderson, NASA TN's D-4883 and D-5264, 1968 and 1969. "Incompressibly Lubricated Rayleigh Step Journal Bearing, I - Zero-Order Perturbation Solution" and "II - Infinite Length Solution," Bernard J. Hamrock and William J. Anderson, NASA TN's D-4839 and D-4873, 1968. "Rayleigh Step Journal Bearing, Part II - Incompressible Fluid," B. J. Hamrock and W. J. Anderson, J. Lubrication Technology, Trans. ASME, Vol. 91, No. 4, pp. 641-650, 1969.
- (7040)
A COMPENDIUM ON THE DESIGN OF TURBOPUMPS AND RELATED MACHINERY.
- (c) Cavour H. Hauser, MS 5-9, Head, Single Stage Compressor Section, Fluid System Components Division.
- (d) Exposition of theoretical and applied research.
- (e) The objective is to compile pertinent information on turbopumps developed by NASA, the various contract research and development programs, and in-house research. This information will be correlated and considered in proper perspective to provide a coherent presentation of the important principles of turbo-machinery design. The Compendium will be published as a NASA Special Publication.
- (g) Effort on writing the Compendium has just been initiated.
- (7041)
PROPELLANT REORIENTATION IN REDUCED GRAVITY ENVIRONMENTS.
- (c) Donald A. Petrash, Chief, Space Environment Branch.
- (d) Experimental; applied research.
- (e) To investigate the effect of the application of a low-level acceleration on the subsequent fluid motion in a space vehicle propellant tank initially in a zero-gravity environment.
- (f) Completed.
- (g) The effects of liquid properties, initial liquid filling and low-level acceleration magnitude on the fluid motion have been correlated with known system parameters for cylindrical and spherical propellant tanks.
- (h) "Experimental Investigation of Liquid-Propellant Reorientation," J. A. Salzman, W. J. Masica, NASA TN D-3789, January 1967. "Liquid Reorientation in Spheres by Means of Low-G Accelerations," T. L. Labus, W. J. Masica, NASA TMX-1659, October 1968.
- (7042)
PROPELLANT TRANSFER TO SPACE VEHICLE TANKS IN ZERO GRAVITY.
- (c) Donald A. Petrash, Chief, Space Environment Branch.
- (d) Experimental; applied research.
- (e) To investigate the effect of a zero-gravity environment on the behavior of the liquid-vapor interface during inflow to a space vehicle tank with primary consideration to minimizing fluid loss through vent.
- (f) Completed.
- (g) The effects of liquid properties, tank size and tank geometry on interface behavior during inflow have been determined in zero-gravity. Results have also been obtained on the effect of initial tank fill level and internal tank baffling.
- (h) "An Experimental Study of Liquid Flow into a Baffled Spherical Tank During Weightlessness," C. R. Andrachio, K. L. Abdalla, NASA TMX-1526, April 1968. "Liquid Inflow to Initially Empty, Hemispherical Ended Cylinders During Weightlessness," E. P. Symons, R. C. Nussle, K. L. Abdalla, NASA TN D-4628, June 1968. "Observations of Interface Behavior During Inflow to an Elliptical Ended Cylinder in Weightlessness," E. P. Symons, R. C. Nussle, NASA TMX-1719, Jan. 1969. "Liquid Inflow to Partially Full, Hemispherical-Ended Cylinders During Weightlessness," E. P. Symons, NASA TMX-1934, December 1969.
- (7043)
LIQUID VAPOR INTERFACE CONFIGURATION AS A FUNCTION OF GRAVITY LEVEL.
- (c) Donald A. Petrash, Chief, Space Environment Branch.
- (d) Experimental; applied research.
- (e) To investigate the effect of a reduced gravity environment on the behavior of the liquid-vapor interface in space vehicle propellant tanks and life support systems.

- (f) Completed.
- (g) The effects of fluid properties, tank size and gravity level have been determined for spheroidal and toroidal tanks. Results have been obtained in both zero- and reduced-gravity environments.
- (h) "Liquid-Vapor Interface Configurations in Toroidal Tanks During Weightlessness," E. P. Symons, K. L. Abdalla, NASA TN D-4819, October 1968.
- "Low-Gravity Liquid-Vapor Interface Configurations in Spheroidal Containers," J. A. Salzman, NASA TN D-5648, February 1970.

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NATIONAL OCEANOGRAPHIC INSTRUMENTATION CENTER,
Washington, D. C. 20390. Gilbert Jaffee, Director.

- (6452)
OCEANOGRAPHIC CURRENT METER CALIBRATION.
- (d) Experimental, development.
- (e) To develop and provide an environmental laboratory facility for the study of improved instrumentation methods in measuring ocean current flow and for testing and calibrating of ocean meters under non-turbulent flow conditions.
- (g) Non-turbulent flow is obtained in a recirculating water current system through the low-velocity range from 0.01 to 5.0 knots. The undisturbed space inside the flow tank provides the necessary water volume for test and calibration of presently used rotor-type current meters and for metrological investigation of flow measurement techniques.
- (h) "Very Low Speed Water Current Facility," A. Carnvale and W. S. Wong, Instrumentation Dept., National Oceanographic Instrumentation Center (unpublished).

- (7053)
PERFORMANCE AND DETERIORATION DATA COLLECTION PROGRAM.
- (d) Field investigation; development.
- (e) Collect and disseminate instrument performance and deterioration data as a means of acquiring statistically significant samples on which to base design criteria for improved systems.
- (g) The Program Plan, reporting form and instructions for inserting information into the Program have been completed. Evaluation of the form and instructions by selected activities in the oceanographic community has been completed. The ADP program for centrally recording the data are being written.

- (7054)
ANCHOR RELEASE MECHANISM RELIABILITY RESEARCH.
- (d) Experimental, development.
- (e) Determine the reliability evaluation criteria. Use the criteria to obtain the reliability of "off-the-shelf" anchor release mechanisms.
- (g) A review of published material revealed that virtually no reliability evaluation of anchor release mechanisms has been performed as a result of questionnaires sent to users and manufacturers.

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UNITED STATES NAVAL ACADEMY, DEPARTMENT OF THE NAVY,
Engineering Department, Annapolis, Maryland 21402.
Captain R. W. King, Head.

- (6130)
THE NATURE OF A PULSE IN VORTEX SINK FLOWS.
- (b) Office of Naval Research.
- (c) Robert Granger, Associate Professor.
- (d) Experimental and basic research.

- (e) Experimental evidence supports theory that a pulse with origin at the sink behaves as a ring vortex and that such behavior occurs in a shear flow past a corner.
- (f) Completed.
- (g) A new dimensionless parameter characterizes the velocity of the surge with circulation of the vortex.
- (h) Paper is to be submitted to J. Fluid Mechanics.

- (6131)
ON A MATHEMATICAL MODEL OF A FORCED VORTEX.
- (b) Office of Naval Research.
- (c) Robert Granger, Associate Professor.
- (d) Theoretical and experimental research.
- (e) A mathematical model of an incompressible steady three-dimensional viscous vortex flow of arbitrary injection flow rate, fluid column height, sink orifice geometry and viscosity is found and compares within 10% of experimental results of velocity field, vorticity, core radius and circulation.
- (f) Completed.
- (h) Paper to be submitted to AIAA.
- (7044)
BOUNDARY-LAYER INDUCED VIBRATIONS.
- (b) O.N.R. through Naval Academy Research Council.
- (c) Dr. Michael E. McCormick, Associate Professor of Ocean Engineering.
- (d) Experimental.
- (e) An experimental investigation is made of the interaction of boundary layer turbulence and a compliant surface.
- (f) Some results accepted by J. Applied Mechanics for publication.

- (7045)
AXISYMMETRIC-VIBRATIONS OF A FLUID-FILLED CYLINDRICAL SHELL SUBMERGED IN A HEAVY FLUID.
- (b) O.N.R. through Chesapeake Instrument Corporation.
- (c) Dr. Michael E. McCormick, Assoc. Prof. of Ocean Engineering.
- (d) Theoretical.
- (e) The effects of the presence of internal and external fluids on the free and forced vibrations of a finite cylinder and the internal pressure fluctuations are studied.
- (f) Publications: C.I.C. Report 69-R-002; C.I.C. Report 69-R-005; C.I.C. Report 69-R-006; J. Hydro-nautics 4, No. 1, January 1970.

- (7046)
THE CONCEPTUAL DESIGN OF A HIGH PERFORMANCE TOWING TANK.
- (c) Dr. Bruce Johnson, Director, Hydromechanics Laboratory.
- (d) Design of a new facility.
- (e) The conceptual design of a 380' by 26' by 16' towing tank capable of speeds up to 50 feet per second was investigated. The tank will be part of the new Engineering Studies Complex at the Naval Academy and is being designed to support Naval Architecture, Ocean Engineering and Oceanography studies, as well as research in flow-induced noise and general hydrodynamics.
- (f) The first phase, the conceptual design is completed. A preliminary design by an outside contractor is nearly completed, and work has begun on the engineering design.
- (g) The preliminary design studies have supported the conceptual design in principle, but significant changes have been made in the details of the carriage configuration, the type of rails, and in the carriage suspension. A report on the preliminary design is in preparation.

- (h) The conceptual design was presented at the 15th Amer. Towing Tank Conf., Ottawa, June 1968. It has been published as Engrg. Dept. Report E-68-5, by Compton, Dyer, and Johnson, and is available from the Engrg. Dept., U. S. Naval Academy.

(7047)

ON THE ADDED-MASS OF A PULSATING CYLINDER.

- (b) O.N.R. through Chesapeake Instrument Corporation.
(c) Dr. Michael E. McCormick, Associate Professor of Ocean Engineering.
(d) Theoretical.
(e) An acoustic-pressure method is used to derive the expression for the added-mass of a radially vibrating cylinder in an infinite fluid.
(f) Published as C.I.C. Report 69-R-001 and accepted by J. Applied Mechanics for publication.

(7048)

RELATIONSHIP BETWEEN VOLUME RATE OF FLOW AND CIRCULATION IN AN AXISYMMETRIC VORTEX FLOW.

- (b) Office of Naval Research.
(c) Robert Granger, Associate Professor.
(d) Experimental.
(e) A relationship between sink volume rate of flow and circulation is found in terms of arbitrary fluid column height, sink orifice radius and kinematic viscosity.
(f) Completed.
(h) USNA Engrg. Report E-69-9.

(7049)

MEASUREMENT OF THE CIRCUMFERENTIAL VELOCITY IN A VORTEX FLOW USING HOT-FILM ANEMOMETRY.

- (b) Office of Naval Research.
(c) Robert Granger, Associate Professor.
(d) Experimental.
(e) The circumferential velocity was measured at various injection locations and in the steady flow field of a viscous incompressible vortex flow using hot-film techniques.
(f) Completed.
(h) USNA Engrg. Report E-69-8.

(7050)

ON THE FEEDING OF FORCED VORTEX FLOWS.

- (b) Naval Ship Research and Development Center.
(c) Robert Granger, Associate Professor.
(d) Experimental.
(e) Experimental investigation in how a vortex is fed and the origin and mechanism of reversed axial flow in the flow field.

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NAVAL CIVIL ENGINEERING LABORATORY, FACILITIES ENGINEERING COMMAND, U. S. NAVY, Port Huene, California 93041. Director, Amphibious and Harbor Division, Code L55.

(6332)

RUN-UP ON A BEACH OF IMPULSIVELY GENERATED SURFACE GRAVITY WAVES FROM A NEAR-SHORE DISTURBANCE.

- (b) Defense Atomic Support Agency.
(d) Primarily experimental; basic and applied research.
(e) Investigation, primarily through measurements in a 90- by 90- by 3-foot basin, of the height of run-up of the leading waves of a dispersive train, as a basis for prediction.
(f) Completed.
(g) Underwater explosions of shallow-water type were simulated. The first four or five waves were dominant, because of limited dispersion. The height of the leading crest varied from 50% to 120% of that of the highest following wave, at a

reference point in shoaling water where dispersion was practically complete. (This depth varied from $g T_1^2/100$ to $g T_1^2/40$. T_1 is the period between the first and second crests.) The leading crest did not break on a moderately smooth, uniform slope of 1:14 for wave heights at the reference point at least as great as 8% of the depth, nor on a 1:20 slope if the wave height was less than 3% of the depth. The run-up of the leading crest was always the greatest and amounted to about 3 times the wave's height.

- (h) "Wave-Basin Study of Run-Up on Beaches from Simulated Underwater Explosions Near Shore," D. B. Jones, Naval Civil Engrg. Lab. Tech. Rep. No. R-604, 55 pages, Dec. 1968 (available from CFSTI, Springfield, Va. 22151).

(6333)

RUN-UP ON PLANE-FACED WALLS OF IMPULSIVELY GENERATED SURFACE GRAVITY WAVES FROM A NEAR-SHORE DISTURBANCE.

- (b) Defense Atomic Support Agency.
(d) Primarily experimental; basic and applied research.
(e) Measurements in a 90- by 90- by 3-foot basin of the height of run-up of the leading waves of a dispersive train on plane-faced, vertical and inclined walls mounted on a sloping bottom at varying distances from shore; to provide a basis for prediction.
(f) Completed.

- (g) For test conditions the same as those described under (6332) and for steep, plane-faced walls, the highest run-up is produced by the leading crest if the wall is located at or above the still-water shoreline; the height of run-up is slightly less than on the unobstructed beach unless the wave approaches the breaking point. If the wall is located where the water is too deep for any wave in the train to break near the wall, the highest run-up (clapotis) is produced by the highest wave. For intermediate locations of the wall, the highest run-up is produced by the wave which is closest to breaking upon arrival at the wall; the run-up height varied up to 5 times the wave height.

- (h) "Measurements of Runup on Seawalls of Waves from Simulated Underwater Explosions Near Shore," D. B. Jones, Naval Civil Engrg. Lab. Tech. Rep. No. R-643, 71 pages, Sept. 1969 (available from CFSTI, Springfield, Va. 22151).

(6335)

HYDRODYNAMIC PRESSURE ON A VERTICAL WALL DUE TO AN INCIDENT DISPERSIVE TRAIN OF SURFACE GRAVITY WAVES.

- (b) Defense Atomic Support Agency.
(d) Experimental; basic and applied research.
(e) Measurement of pressure histories on wall with incident breaking and non-breaking waves.
(f) Completed.
(g) The wave-induced force was found to have two phases -- (1) an impact phase and (2) a slowly varying phase which is mostly hydrostatic. The ratio of peak impact force to maximum hydrostatic force was 3.26. The results suggest that wave-induced impact is most severe for breakwaters and seawalls constructed of several courses of large blocks which rely solely upon friction for shear resistance between courses.
(h) "Water Waves from Underwater Explosions in Shallow Water, Part II: Characteristics of Waves Near the Shoreline and Method of Estimating Wave Forces on a Vertical Barrier," H. Wang, Naval Civil Engrg. Lab. Tech. Note No. N-945, 56 pages, January 1968.
"Forces Induced on a Vertical Barrier by a Dispersive Wave Train," D. Davis, Naval Civil Engrg. Lab. Tech. Note No. N-990, 54 pages, Sept. 1968.

(7051)
RESPONSE OF A LIGHTWEIGHT FLOATING CAUSEWAY IN SURF.

- (b) Director of Navy Laboratories.
- (d) Experimental; applied research.
- (e) To determine the conditions in which a string of lightweight (40 psf) barges, arranged end to end, would be suitable as a floating causeway or pier, measurements of the displacements and accelerations of a four-barge model (1:40 scale) were made in a wave tank. A string of four 90- by 22- by 4-foot (prototype) Ammi pontoons was arranged along the center-line of the wave tank, over a 1:25 slope, with one end pinned at the shoreline. The third barge from the shore was in the surf zone. Various means of restraint were investigated, including pin connections between barges, pile-guides run through spud wells near the corners of the barges, and combinations of these types. Wave periods varied from 6 to 19 seconds. Wave heights varied from 1.7 to 10 feet.
- (f) Completed.
- (g) For wave environments not considered to be uncommon, the motion of the end barge was great enough to restrict significantly operations involving the mating of LSTs and of ships.
- (h) "Hydrodynamic Response of Ammi Causeway in Surf Zone - V LAP," J. A. Drellicharz, Naval Civil Engrg. Lab. Tech. Note No. N-1052, 95 pages, Jan. 1970.

(7052)
EFFECT OF NUCLEAR EXPLOSIONS ON DEEP OCEAN STRUCTURES.

- (d) Theoretical, applied research.
- (e) The response of elastically-restrained, rigid, spherical and cylindrical structures to weak underwater shock waves is being studied. This is a preliminary study for the purpose of developing criteria for the design of hardened deep ocean structures.
- (g) The response to exponentially attenuated shock waves has been obtained through the use of linear acoustic theory and Fourier transform methods. For a spherical structure, the Fourier transform of the structure's response was obtained exactly. For a cylindrical structure, a numerical procedure was required; the numerical method was tested on the spherical problem and found to be adequate.
- (h) "Rigid Body Response of an Elastically-Restrained Cylindrical Deep Ocean Structure to Detonation-Induced Underwater Shock," H. S. Zwiibel and J. G. Hammer, Naval Civil Engrg. Lab. Tech. Note No. N-1062, 28 pages, November 1969.

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U. S. NAVAL OCEANOGRAPHIC OFFICE, Washington, D. C. 20390. Boyd E. Olson, Scientific and Technical Director.

(6454)
WAVE FORECASTING RESEARCH.

- (c) Mr. John J. Schule, Jr., Director, Research and Development Department (Code 70).
- (d) Applied research involving field experiments with wind-generated ocean waves.
- (e) Development of automated wave prediction techniques on an oceanwide basis; present emphasis is directed to measurement and interpretation of directional wave spectra obtained with airborne laser wave profiler and parameterization of surface drag through study of low level winds from towers and ships.
- (h) "Observations of Higher Frequency Components of Fetch-Limited Wave Height Spectrums with an Airborne Laser Wave Profiler," J. J. Schule, et al., in preparation.

"Momentum Flux Observations from Argus Island Tower," P. S. De Leonibus, in preparation.

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U. S. NAVAL ORDNANCE LABORATORY, White Oak, Silver Spring, Maryland 20910. Dr. G. K. Hartmann, Technical Director.

(4867)
HYDROBALLISTICS RESEARCH.

- (b) Naval Ordnance Systems Command.
- (c) Dr. A. E. Seigel, Chief, Ballistics Department.
- (d) Experimental, theoretical; basic and applied research.
- (e) The purpose is to study high velocity water entry as related directly or indirectly to the behavior of missiles. The study includes the stability and forces during the entry, cavity development and pressure, and the missile trajectory. A wide range of developmental and research configurations and of experimental conditions are investigated. The missiles are launched from gas or powder guns. A large tank facility was completed near the end of 1966. This facility, which was designed for use with large, high-speed missiles, is supplemented by a smaller, lower-speed tank. Both tanks are suited to such experimental projects as water entry, water exit, and trajectory studies, and both permit atmospheric pressure reduction for water-entry scaling. Current programs involve: axial impact forces, pressure in the water-entry cavity, propulsion and stability of nonbuoyant missiles, and prevention of vortex shedding.
- (g) Results of recent studies include: prediction of water entry drag coefficients for ogives from cone data; experimental determination of water entry cavity pressure; steady state drag coefficients of various cavitating head forms; measurements of the virtual mass of cones during entry and the effect of the air-water interface; the behavior of the water-entry cavity during formation and closure.
- (h) "The Cavity After Vertical Water Entry," Albert May, NOLTR 68-114, 1968.
"The Behavior of the Cavity Formed by a Projectile Entering the Water Vertically," Harvey I. Abelson, Ph.D. thesis, Univ. of Maryland, June 1969.
"Preliminary Analysis of the NOL Hydroballistics Blowdown Water Tunnel," V. C. D. Dawson and A. E. Seigel, NOLTR 68-190, February 1969.
"A Method of Stabilizing Cylinders in Fluid Flow," D. W. Sallet, J. Hydronautics, Vol. 4, No. 1, p. 40, January 1970.
"On the Spacing of Karman Vortices," D. W. Sallet, J. Applied Mechanics, Vol. 36, Series E, No. 2, pp. 370-372, June 1969.
"On the Self-Excited Vibrations of a Circular Cylinder in Uniform Flow," Dirse W. Sallet, Shock and Vibration Bulletin, No. 40, Part 3, Dec. 1969.

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U. S. NAVAL POSTGRADUATE SCHOOL, Department of Aeronautics, Monterey, California 93940. Dr. R. W. Bell, Department Chairman.

(6588)
COMPUTER SIMULATION OF TURBULENCE.

- (c) Professor T. H. Gawain, Code 576n.
- (d) Theoretical; basic research for Ph.D.
- (e) The energy transfer from a shear flow to turbulence is being investigated, using a computer.
- (g) Report forthcoming in 1970. Also see J. Computational Physics, June 1970.

- (6589)
UNSTEADY AERODYNAMICS.
(c) L. V. Schmidt, Associate Professor, Code 57Sx.
(d) Experimental and theoretical; basic research at Ph.D. level.
(e) Unsteady aerodynamics .. separated and potential flow. Motion dependence in bluff body aerodynamics, pressure fields of low aspect ratio lifting surfaces, and body interference, utilizing low-cost transducer concept of Bergh which is ideally suited for aeroelastic models.
- (6882)
HOLOGRAPHIC INTERFEROMETRY.
(b) Naval Air Systems Command.
(c) Professor D. J. Collins, Code 57Co.
(d) Experimental and theoretical applied research.
(e) Application of Q switch holography to the determination of complex three-dimensional density field.
(g) Final reports and written article on project to be issued June 1970.
- (6883)
HELICOPTER BLADE STALL.
(c) J. A. Miller, Associate Professor, Code 57Mo.
(d) Experimental; applied research for Ph.D.
(e) Wind tunnel simulates harmonic variation in velocity stall of helicopter blades; measurements using pressure taps, tufts and hot wire anemometers.
(g) Definition of separation in such flows includes correlation of separation point shift with amplitude, frequency and boundary layer dynamic history. Performance at high angles of attack departs markedly from that predicted by quasi-steady aerodynamics.
(h) "Heat Transfer in the Oscillating Turbulent Boundary Layer," J. Engineering for Power, Trans. ASME, Series D, Vol. 91, No. 4, 1969. Other articles forthcoming in 1970.
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- U. S. NAVAL POSTGRADUATE SCHOOL, Department of Mechanical Engineering, Monterey, California 93940. Dr. T. Sarpkaya, Department Chairman.
- (6058)
JET ATTACHMENT TO OFFSET CONVEX COANDA WALLS.
(b) Dept. of the Army, Harry Diamond Laboratories.
(c) Dr. T. Sarpkaya and Dr. Thomas Houlihan.
(d) Theoretical and experimental study of the pressure and velocity distribution over a convex wall set back relative to the power jet. Basic research for M.S. thesis.
(e) Primary objective of the research is to establish the significance of the wall curvature on the coanda effect.
(g) Preliminary studies show that a convex-walled bistable amplifier has a relatively higher pressure recovery.
(h) "Performance Characteristics of Straight, Concave, and Convex Walled Vented and Unvented Bistable Amplifiers," T. Sarpkaya, Internal Report to Harry Diamond Laboratories, July 1967.
"The Performance Characteristics of Geometrically Similar Bistable Amplifiers," T. Sarpkaya, J. Basic Engrg., Trans. ASME, 91, 2, pp. 257-263 (June 1969).
"Turbulent Jet Over an Inclined Wall," T. Sarpkaya and D. C. Richardson, ASME Paper No. 69-WA/FLCS-1, 1969.
- (6059)
SWIRLING FLOWS IN TUBES AND VORTEX BREAKDOWN.
(b) Dept. of the Army, Harry Diamond Laboratories.
- (d) Theoretical and experimental work for M.S. thesis.
(e) To determine the circulation distribution in tubes and the effect of the adverse pressure gradient on vortex breakdown.
(h) "Forced and Periodic Vortex Breakdown," T. Sarpkaya, J. Basic Engrg., Trans. ASME, Sept. 1967, pp. 609-616.
"A Theoretical and Experimental Investigation of a Confined Vortex Oscillation," T. Sarpkaya, C. Pavlin, and S. Phasook, ASME Paper No. 69-WA/FLCS-1, 1969.
- (6060)
A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF WIND-INDUCED OSCILLATIONS OF ELASTIC BODIES.
(b) National Aeronautics and Space Administration.
(d) Theoretical and experimental work for M.S. and Ph.D. theses.
(e) Life and drag forces and the frequency of the oscillations of slender bodies subjected to wind forces are determined through the use of discrete vortices and potential flow theory.
(g) Preliminary studies show that the potential flow analysis may be used to accurately predict the drag forces and to establish an appropriate scale factor.
- (6061)
A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF VIRTUAL MASS IN STRATIFIED FLUIDS.
(d) Theoretical and experimental work for M.S. thesis.
(e) To determine the virtual mass and the forces acting on a body immersed in a uniformly stratified fluid.
(g) Experiments are being conducted using salt water solution in a rectangular tank with circular cylinders of various diameters. The cylinder is oscillated with frequencies ranging from 0.5 to 6 cps. The forces are recorded with the help of a strain gage transducer.
- (6062)
THRUST CONTROL IN A TRANSONIC NOZZLE WITH SWIRLING FLOW.
(d) Theoretical and experimental study of the velocity and pressure distribution and the thrust in a transonic nozzle. Applied theoretical and experimental research for M.S. thesis.
(e) Primary objectives of the research are to determine the relationship between the mass flow used in the generation of the vortex motion to the thrust provided by the nozzle and to develop a non-moving system of thrust control through the use of the vortex motion.
(g) Preliminary studies show that the magnitude of the thrust may be varied from 100% to 60% with a swirled mass flow to nozzle mass flow ratio ranging from 0 to 20%.
- (7056)
A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF JET INTERACTION IN BEAM-DEFLECTION AMPLIFIERS.
(b) Army Research Office (Durham).
(d) Theoretical and experimental study of the velocity and turbulence distributions in the interaction region of the jets. Basic research for M.S. and Ph.D. theses.
(e) To study jet pinching, resultant jet deflection, noise sources and distribution, the effects of setback and control-port width and Reynolds number on the amplifier gain, and the modeling laws.
(h) "A Theoretical and Experimental Investigation of the Interaction of Jets in Beam-Deflection Type Fluidic Elements," T. Sarpkaya, S. B. Weeks, and G. L. Hiriart, Proc. 4th Cranfield Fluidics Conf., March 1970. Published by British Hydromechanics.

(7057)

FLOW OF DILUTE POLYMER SOLUTIONS ABOUT HYDROFOILS.

- (b) Naval Ship Research and Development Center.
- (d) Theoretical and experimental study of the flow of second-order viscoelastic fluids and the lift and drag characteristics of hydrofoils immersed in dilute polymer (WSR-301) solutions. Ph.D. thesis.
- (e) The effect of polymers on the lift and drag of hydrofoils is being studied through the use of a water tunnel.
- (g) The results obtained with circular cylinders show that the maximum drag reduction occurs with 25 wppm solution of WSR-301 whereas the maximum shift of the separation point occurs with 100 ppm, indicating that the drag reduction phenomenon is not merely a consequence of the reduction of the wake size but also a consequence of the change of the wake vortex characteristics with viscoelasticity.
- (h) "Stagnation Point Flow of a Second Order Viscoelastic Fluid," T. Sarpaya and P. G. Rainey, *Acta Mechanica* (in press).

(7058)

SLOT JET INJECTION INTO SUBSONIC AND SUPERSONIC STREAM.

- (b) Naval Weapons Center, China Lake, California.
- (c) Dr. Robert H. Nunn.
- (d) Theoretical and experimental. Basic research for M.S. thesis.
- (e) Primary objectives of the research are to determine the size of the separation region and the characteristics of the mixing region.

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U. S. NAVAL POSTGRADUATE SCHOOL, Department of Oceanography, Monterey, California 93940. Dr. D. F. Leipper, Department Chairman.

(6595)

BOUNDARY LAYER TURBULENCE.

- (b) Naval Ordnance Systems Command, Washington, D. C.
- (c) Dr. Warren W. Denner and Noel E. J. Boston, Assistant Professors.
- (d) Theoretical and experimental research.
- (e) The turbulent microstructure of the wind and temperature fields immediately above wind generated waves is being investigated. The purpose is to determine the significance of this layer by transporting heat and momentum.
- (g) Turbulent wind and temperature measurements have been made from 1 cm to 80 cm over the sea surface at Spanish Banks (near Vancouver, B. C.). Sensors were mounted in pairs, one at a fixed height and one on a wave follower. Preliminary analysis indicates waves influence the wind and temperature fields only very near (less than a wave height above) the sea surface.
- (h) "Temperature Fluctuations Above an Air-Water Interface," N. E. J. Boston, J. R. Ramzy, E. T. Young, Jr., and T. Green, III. 6th U. S. Navy Symposium on Military Oceanography, May 1969.
"Digital Analysis of Turbulence Data on the IBM 360/67 at the Naval Postgraduate School," Tech. Rep. NPS-58DW9071A, July 1969.

(7059)

ARCTIC MICROSTRUCTURE AND ACOUSTIC PROPAGATION.

- (b) Naval Ordnance Systems Command, Washington, D. C.
- (c) Dr. Warren W. Denner, Assistant Professor.
- (d) Theoretical and field investigations of the microstructure in the arctic and the interaction of acoustic waves with this microstructure.

- (e) Measurements of the thermal microstructure and acoustic wave interaction are being made and analyzed.
- (g) The vertical thermal microstructure in the arctic has been measured to a resolution of $2 \times 10^{-4}^{\circ}\text{C}$ and the water between 200 and 350 m has been found to consist of sharply defined layers.
- (h) "Thermal Stratification in the Arctic Ocean," V. T. Neal, S. Neshyba and W. W. Denner, *Science*, Vol. 166, Oct. 17, 1969, pp. 373-374.

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U. S. NAVAL POSTGRADUATE SCHOOL, Department of Physics, Monterey, California 93940. Dr. O. Heinz, Department Chairman.

(7060)

DAG COEFFICIENTS OF SPHERES IN DILUTE AQUEOUS SOLUTIONS OF HIGH POLYMERS.

- (b) Naval Ordnance Systems Command, Washington, D. C.
 - (c) J. V. Sanders, Associate Professor.
 - (d) Experimental, Master's thesis.
 - (e) Terminal speeds of freely falling spheres are used to determine drag coefficients and Reynolds numbers (based on viscosity of water) for various polymer concentrations and types and for a range of sphere size and density. Reynolds numbers obtained extend from Stokes region to above the critical Reynolds number.
 - (g) For Reynolds numbers less than 10^4 , drag increases as polymer concentration increases. For Reynolds numbers above 10^4 but less than the critical value, drag decreases until polymer concentration reaches an optimum (100 wppm WSR-301) and then increases with further increase in concentration. The polymer does not appear to change the value of the critical Reynolds number. Behavior above critical appears to show drag reduction.
 - (h) "Drag Coefficients of Spheres on Poly(ethylene oxide) Solutions," J. V. Sanders, *Int. Shipbuilding Progress*, 14, 152, 146-157 (1967).
"Drag of Free Falling Spheres in Dilute Aqueous Solutions of Poly(ethylene oxide) for Reynolds Numbers Above the Critical Value," E. F. Woolery, Thesis, Dec. 1968, Naval Postgraduate School (DDC Cameron Station, Alexandria, Virginia 22314).
- (7061)
- EFFECT OF DRAG-REDUCING POLYMERS ON THE HYDRODYNAMIC BEHAVIOR OF SURFACE-PIERCING STRUTS.**
- (b) Office of Naval Research, Washington, D. C.
 - (c) J. V. Sanders, Associate Professor.
 - (d) Experimental, Master's thesis.
 - (e) A circular-cylinder was towed in dilute solutions of high polymers and preliminary observations were made of the following: surface wake, oscillatory lift and drag, and ventilation cavity.
 - (f) Suspended.
 - (g) Surface wake: Photographs showed that in polymer solutions the visible wake was significantly reduced. Oscillatory lift and drag: Magnitude and spectrum were not appreciably affected. Ventilation cavity: With addition of polymer, the line where the cavity wall is attached to the cylinder changed from a straight to a serrated appearance.
 - (h) "Surface Wake of a Circular Cylinder in Dilute Aqueous Solutions of Poly(ethylene oxide)," M. H. Fletcher, Thesis, June 1969, Naval Postgraduate School, Monterey, California (DDC, Cameron Station, Alexandria, Virginia 22314).
"Oscillatory Forces on a Semi-Submerged Circular Cylinder in Water and in Dilute Aqueous Solutions of Poly(ethylene oxide)," S. M. Genstil, Thesis, June 1969, Naval Postgraduate School.

(7062)
CORRELATION OF PIPE-FLOW DRAG-REDUCTION AND MOLECULAR DEGRADATION.

- (b) Office of Naval Research, Washington, D. C.
- (c) J. V. Sanders, Associate Professor.
- (d) Experimental; Ph.D. thesis.
- (e) Measurements are made of the intrinsic viscosity of dilute aqueous solutions of high polymers, both before and after pipe friction-factor measurements. A range of pipe diameters and polymer concentrations and types will be tested for Reynolds numbers (based on water) extending from the laminar region to as high as feasible.

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U. S. NAVAL RESEARCH LABORATORY, Washington, D. C.
20390. James C. Matheson, CAPT, USN, Director.

(7063)
DIFFUSIVITY OF HEAT AND SALINITY IN WATER.

- (c) Dr. Allen H. Schooley, Code 8303, Building 208.
- (d) Experimental exploratory applied research.
- (e) Molecular and eddy diffusivity in water is measured with no turbulence and controlled amounts of increasing turbulence.
- (g) The ratio of molecular thermal diffusivity to molecular diffusivity of salt (sodium chloride solution) in water is about 130. As turbulence is increased the ratio of the eddy diffusivities decrease, and may approach unity.

(7064)
VISCOS FLOW IN THE AIR AND WATER WITHIN THE MEAN LAMINAR SUBLAYERS AT THE NAVIFACE (SEA-AIR INTERFACE).

- (c) Dr. Allen H. Schooley, Code 8303, Building 208.
- (d) Phenomenological applied research.
- (e) Heat balance equations have been applied to sea measurements to determine the average thickness, temperature difference, and stress across the thin viscous sublayers in the air and in the water at the naviface.
- (g) Heat balance at the sea surface is assumed to be dominated by the equation, $\dot{Q}_h \pm \dot{Q}_a \pm \dot{Q}_w \pm \dot{Q}_e = 0$ cal/cm²/min, where \dot{Q}_h is the net all-wave radiation balance. \dot{Q}_a is the molecular conduction of sensible heat through the average thickness of an assumed nonturbulent air layer in contact with the sea surface. \dot{Q}_w is the molecular conduction of sensible heat through the average thickness of an assumed nonturbulent laminar sublayer in the water very near the surface. \dot{Q}_e is the contribution of the latent heat of evaporation. Balancing this equation under conditions of sunshine and cloud cover at sea, has given new comparisons regarding the relative thickness of the average laminar sublayers, their temperature differences, and wind stresses.

(7065)
MICROWAVE SCATTERING FROM WIND WAVES.

- (c) Dr. John W. Wright, Code 5272.
- (d) Experimental investigation of doppler spectra in microwave scattering from wind waves in a short fetch laboratory wind/wave tank together with measurements of water wave slope spectra by photographic techniques.
- (g) Scattering mechanism is low order Bragg scattering. Doppler bandwidth is proportional to windspeed and Bragg wave number. Doppler bandwidth at low angles scales with fetch much as does the orbital velocity.
- (h) "Slope Spectrum of Capillary Waves in a Wave Tank," W. C. Keller, NRL Report of Progress, pp. 18-19, February 1969.

(7066)
WAKE EXPANSION IN SIMULATED ENVIRONMENTS.
(c) Kingsley C. Williams, Code 8340, Building 68.

- (d) Experimental exploratory research.
- (e) Models are used to study wake expansion phenomena in complex environments, including density gradients and overturn.

(7067)
SEA SPECTRA ANALYSIS.

- (c) Denzil Stilwell, Jr., Code 5273.
- (d) Field investigation of a novel technique of sea spectra measurement and basic research into the behavior of the sea surface.
- (e) This project involves the processing of photographs of the sea surface taken under specified conditions to obtain the two-dimensional energy density spectrum of the height variations on the sea surface. This is accomplished by analyzing the diffraction pattern of the density variations on the sea photograph and relating it to the energy density spectrum. In addition, studies of the ocean wave spectra are being made from an EC-121 platform to determine the magnitude and variability of the sea surface.
- (g) The Sea Photo Analysis (SPA) technique has been verified by simultaneous measurement of the sea surface variation by SPA and by wave staffs. The technique has also been verified in laboratory wave tanks. Work is continuing to use SPA on aerial photos taken from the EC-121 platform.
- (h) "Directional Energy Spectra of the Sea from Photographs," Denzil Stilwell, Jr., J. Geophys. Res., Vol. 74, No. 8, pp. 1974-1986, Apr. 15, 1969

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U. S. NAVAL SHIP ENGINEERING CENTER, PHILADELPHIA DIVISION, Applied Physics Department, Philadelphia, Pennsylvania 19112. J. W. Murdock, Department Head.

(3623)
HIGH PRESSURE-TEMPERATURE WATER FLOW METER CALIBRATION.

- (d) Experimental; applied research.
- (e) A facility is available for calibrating with water at pressures and temperatures up to 2500 psi and 600°F, respectively. Capacity is 100 gpm at maximum pressure and temperature and greater at lower pressures and temperatures. After flowing through the metering section the water is cooled and weighed. The facility is also used to investigate and verify orifice meter coefficients at pressures and temperatures above those at which the coefficients in use were established. A number of flow meters which measure the flow in nuclear reactor loops have been calibrated.
- (f) Inactive.
- (g) A limited amount of test data indicate good agreement between orifice flow rates obtained by calibration at high pressures and temperatures and those obtained by extrapolating from cold water calibrations. Other meter tests show the need to include suitable corrections for change in shape, size, density, etc.

(7068)
OPTIMIZATION OF DISCHARGE COEFFICIENT FOR FLOW NOZZLES.

- (d) Experimental; applied research.
- (e) Flow nozzle discharge coefficients are a function of boundary-layer displacement thickness. For a given nozzle shape, the throat Reynolds number is directly related to boundary-layer Reynolds number so that correlation of nozzle coefficients can be obtained in terms of R_d . The present state:

of-the-art of the flow nozzle gives discharge coefficients within one percent of unity above a Reynolds number of 1.3×10^5 . The objective of this project is to increase the range of Reynolds number over which the flow nozzle coefficient of discharge is within one percent of unity. It will be necessary to modify basic nozzle design using techniques of boundary-layer control and determine optimal positioning of pressure taps to maximize the discharge coefficient. ASME nozzles are being subjected to the coefficient optimizing design modifications.

- (g) After an initial calibration, the first modification of the pressure tap location for a two-inch ASME nozzle has been completed. The pressure tap is in the throat far upstream of any position ever reported. From theoretical calculations of the boundary layer thickness in the nozzle, it is expected that such a position will result in a nozzle coefficient curve closer to unity than the standard ASME tap loci.

(7069)

THE CALIBRATION CORRELATION FUNCTION FOR POSITIVE DISPLACEMENT LIQUID METERS.

- (d) Experimental; applied research.
- (e) The objective of this project was to enhance understanding of the performance of the precessing (nutating) disk positive displacement flow meter in various fluids. Subsequent application of these findings could improve the reliability of these instruments in service and could be used to reduce the number of fluid states presently needed in meter calibrations.
- (f) Completed.
- (g) A blending of theory and experiment has distilled a correlation function for precessing (nutating) disk oil meters. This correlation function can predict the change in volumetric efficiency, and therefore the meter calibration, due to a change in the fluid conditions with an accuracy of $\pm 1/2\%$. A recent calibration of the particular meter is still necessary, however. The experiments included the meter sizes from 3/4-inch to 2-1/2-inch pipe, but there is little reason to suspect that the correlation would not be valid for the other sizes and fluid conditions. The analysis and approach presented in this report are applicable to all designs of positive displacement flow meters.
- (h) "The Calibration Correlation Function for Positive Displacement Liquid Meters," D. R. Keyser, NAVSEC-PHILADIV Rep. A-770, 16 Dec. 1969 (obtain from DDC, Cameron Station, Alexandria, Va. 22314).

(7070)

A DIFFERENTIAL PRESSURE VISCOMETER FOR NAVY FUEL SYSTEMS.

- (d) Experimental; applied research.
- (e) A research program was initiated to develop a prototype viscometer applicable for Navy fuel systems as a result of a patent disclosure by James W. Murdock of NAVSEC-PHILADIV. Patent No. 3,424,191 for a system that regulates viscosity of liquids using differential pressure measurement was awarded on 28 January 1969. The prototype viscometer was to be a full-flow device rather than a sampling device, capable of in-line application, and utilizing the relationship between the differential pressures across laminar and turbulent flow sections and fluid kinematic viscosity.
- (f) Completed.
- (g) A practical in-line viscometer using differential pressure measurement to measure viscosity has been developed. It consists of two sections, a laminar flow and a turbulent flow section. The

viscometer operates on the principle that the pressure drops produced by laminar and turbulent flows can be correlated with the kinematic viscosity of the fluid in the line. These differential pressure signals could determine and automatically control the viscosity in Navy fuel systems for optimum burning. This report presents the criteria used in designing and experimental results of testing a practical in-line viscometer suitable for shipboard evaluation. The viscometer measured viscosity accurately over a range of 85 to 238 SSU at temperatures from 100 to 147°F in Lube Oil and Navy Special Fuel Oil. The measurement was in terms of a pressure drop ratio ($\beta = \Delta P_L / \Delta P_T$) which was found to be directly proportional to the kinematic viscosity for Reynolds numbers greater than 1000 in a two-inch pipe. The viscometer, practical for Navy use, could control viscosity at the optimum value of 135 SSU independent of the flow rate.

- (h) "A Differential Pressure Viscometer for Navy Fuel Systems," A. E. Sauerwalt, NAVSEC-PHILADIV Report A-830, 4 April 1969 (obtain from DDC, Cameron Station, Alexandria, Virginia 22314).

(7071)

ANALYSIS OF CONICAL ENTRANCE ORIFICE.

- (d) Experimental; applied research.
- (e) Head-type primary elements are, as a class, weak in low Reynolds number ranges. Their coefficients exhibit a large deviation from linearity in this area making their use for many purposes suboptimal at best. A primary element with a relatively flat discharge coefficient could be of significant value in certain shipboard applications. The conical entrance orifice was developed by George Kent Ltd., England. It is asserted to have a flat coefficient of discharge varying from 0.72 to 0.76 over a Reynolds number range of 200 to 50,000. The International Standards Organization Committee ISO/TC 30 has issued a preliminary draft specification for this orifice. In cooperation with both ISO/TC 30 and ASME, analysis of the performance of the conical entrance orifice is being conducted.
- (g) The program to date has been confined to a theoretical investigation of Conical Entrance Orifice performance. The experimental program will commence on receipt of meter sections now being prepared and tested by various interested private companies in the flow measurement field.

(7072)

DETERMINATION OF ELBOW METER FLOW COEFFICIENTS.

- (d) Experimental; applied research.
- (e) Objective is to obtain knowledge of the effects of pipe size and Reynolds number on the flow coefficient of elbow meters in the nominal pipe sizes below 1-1/4-inch and below R_D No. of 70,000.
- (g) A test facility has been erected. The experimental program is now in progress. Results to date are incomplete and not in a reportable form at this time.

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U. S. NAVAL SHIP RESEARCH AND DEVELOPMENT LABORATORY (NSRDL/Annapolis), Annapolis, Maryland 21402.

(6428)

MATERIALS FOR SURFACE EFFECT SHIPS (SES).

- (b) Joint Surface Effect Ships Program Office (JSSEPO).
- (c) A. Ruffolo, Coatings Branch Head (Code A937).
- (d) Experimental; applied research and development.
- (e) Development of coatings and overlay materials which can provide corrosion, erosion and anti-

fouling protection in severe hydrodynamic environments; of structural materials which can resist erosion, primarily that produced by cavitation. Studies are concerned with screening of erosion resistant metallic and elastomeric materials; with development of high strength adhesives; with application techniques; and with field evaluations. Studies are performed in a "Cavitation Laboratory" which comprises (1) a rotating disk apparatus, (2) magnetostriction equipment, (3) a high speed Venturi nozzle facility, and (4) a high sonic energy test tank. Field trials have included experimental applications on propellers and on Navy hydrofoils. Work has been concentrated on materials for application to high speed Captured Air Bubble (CAB) vehicles.

- (g) Attachment, demonstrated to be a critical problem, has been achieved with moderate success on hydrofoils, through special attachment techniques and high strength adhesives. Materials (metallic and elastomeric) with high resistance to cavitation erosion have been evaluated and catalogued. Several protective materials and seal materials have been selected as promising candidates for CAB, and a study was made of two candidate aluminum alloys for structural application.
- (h) "Cavitation Erosion Resistance of Structural and Protective Materials," J. Z. Lichtman, Naval Applied Science Lab., Lab. Project 930-114, Progr. Rep. 6, 23 pages, to be published.
- "General Investigation of SES Structural Materials," A. Macander, Naval Applied Science Lab., Lab. Project 930-114, Progr. Rep. 7, 18 pages, 8 Jan. 1970.
- "Preliminary Survey of the State-of-the-Art of Seal Materials for 100-Ton CAB Vehicle," J. Cirignone, Naval Applied Science Lab., Lab. Project 930-114, Progr. Rep. 5, 6 pages, 22 July 1969.
- Distribution of the last three references is controlled by the Joint Surface Effect Ships Program Office (JSESP), Box 3647, Washington, D. C. 20007.

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U. S. NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER,
Pasadena Laboratory, 3202 E. Foothill Boulevard,
Pasadena, California 91107. Officer in Charge.

(4868)

NON-NEWTONIAN FLUIDS.

- (b) Naval Ordnance Systems Command.
- (d) Theoretical; basic research.
- (e) Greater understanding of the basic mechanism of the Toms effect is the aim of this work. The approach taken is to study the rheological properties of friction-reducing fluids in elongational flows. In recent work, emphasis has shifted from experimental studies (e.g., "Indian-rope" and orifice flow) to related analytical investigations in continuum mechanics. Various well-known viscoelastic-fluid equations of state have been compared by considering their responses to extensional flow with a step-function history of principal strain rates. This type of flow can be called "start-extension" flow.
- (g) A seemingly significant finding concerns those models which show a critical extensional strain rate. In such cases, as is well known, no valid solution for extensional viscosity exists for steady-state extension at or above the critical strain rate. This behavior has been taken to be an obvious deficiency of such fluid models. However, the new work shows that such models yield valid solutions for all finite strain rates and all finite times in start-extension flow. Thus, since only finite times are of interest in the real world, the behavior of such fluids for criti-

cal or supercritical strain rates is of interest and possibly has some counterparts in the physical world. Indian-rope flow seems to be such a case. For supercritical extensional strain rates, such fluid models imply very high extensional viscosities. It seems to be a reasonable conjecture that such models may be capable of providing a continuum-mechanical interpretation of the Toms effect.

(6585)

TURBULENT BOUNDARY-LAYER CALCULATIONS.

- (b) Naval Ordnance Systems.
- (c) D. M. Nelson, Code 2542.
- (d) Theoretical; applied research.
- (e) The purpose of this work is to maintain a good state-of-the-art integral method for calculating two-dimensional and axisymmetric turbulent boundary layers. The turbulent boundary layer calculation method has been extended following Alber (Proc., Computation of Turbulent Boundary Layers - 1968 AFOSR-IFP-Stanford Conf.) to include "exactly" equilibrium boundary layers with non-zero pressure gradients. A further extension was made to give the boundary-layer development a "memory" by the use of a lagging shape factor in the calculation of the energy dissipation.
- (g) Comparisons with experimental data show that the extension to give the boundary layer development a "memory" results in a significant improvement in the theoretical predictions.

(7219)

PROPULSOR DESIGN.

- (b) Naval Ordnance Systems Command.
- (c) D. M. Nelson, Code 2542.
- (d) Theoretical, experimental; applied research.
- (e) The objective of this work is to develop advanced theoretical methods for the design of underwater propulsors, to program them for high speed computers, and to apply them to the design of hardware which may be experimentally verified. Work to date has concentrated on the development of a lifting-surface design method for counter-rotating propellers operating on an axisymmetric body.
- (g) The theoretical development and computer programming of the design method is complete. Two sets of counter-rotating propellers have been designed and fabricated. Testing of the propellers is currently being carried out.

(7220)

NUMERICAL ANALYSIS OF REAL FLUID FLOW.

- (c) L. Lopes, Code 4003.
- (d) Theoretical; applied research.
- (e) The purpose is to develop numerical computation techniques for unsteady, two-dimensional, incompressible, viscous fluid flow about airfoils.
- (f) Completed.
- (g) FORTRAN programs for the solution of Navier-Stokes equations and a technique for a computer printout display of flows have been developed.

(7221)

FLOW NOISE - PIPE FLOW STUDIES.

- (b) Office of Naval Research and Naval Ordnance Systems Command.
- (c) J. M. Caraher, Code 2541.
- (d) Theoretical and experimental; applied research.
- (e) The purpose is to study the effects of dissolved high molecular weight polymers on suppressing wall pressure fluctuations beneath a turbulent boundary layer.
- (g) Installation of a 4-inch pipe flow facility has been completed. This flowdown facility will be used with both plain water and polymer solutions

to study the effects on boundary layer pressure fluctuations. Manufacture of piezoelectric transducers for measuring wall pressure fluctuations has been completed and the transducers have undergone a preliminary calibration. Sound damping material has been applied to the pipe and isolating washers have been installed to reduce the structure-borne noise reaching the hydrophones.

(7222)

POLYMER SECRETING ORGANISMS.

- (b) Office of Naval Research.
 - (c) P. R. Kenis, Code 2541.
 - (d) Experimental; applied research.
 - (e) The purpose is to test bacterial polysaccharides for drag reducing effectiveness in a search for more effective materials.
 - (g) Polysaccharides from many bacteria were found to be effective. A polysaccharide from Pseudomonas sp. reduced drag 60% at 60 ppm; Neisseria sp., 60% at 100 ppm; and Arthrobacter viscosus, 45% at 250 ppm. The polysaccharide from Xanthomonas campestris reduced drag 60% at 50 ppm; and is the most effective polysaccharide found to date; however, the synthetic polymers, poly(ethylene oxide) and polyacrylamide, are much more effective on a weight basis.
- Drag reduction measurements were made at different pH values to study molecular conformational changes or cross-linking effects on the drag-reducing properties of bacterial polysaccharides. Polysaccharides from Xanthomonas campestris, Pseudomonas sp., Neisseria sp., and Arthrobacter viscosus exhibited altered drag-reducing properties under various pH units. When pH values were changed, irreversible, partially reversible, and other drag-reducing effects occurred.
- (h) "Turbulent-Flow Properties of Polysaccharide Solutions in Solution Properties of Natural Polymers," J. W. Hoyt, Special Publication No. 23, Chemical Society, London, pp. 207-215, 1968.
- "Effects of pH on the Production of Extracellular Drag-Reducing Polymers," P. R. Kenis, App. Microbiol. 16: 1253-1254, 1968.
- "Microbial Polysaccharides as Friction-Reducing Additives," Bacteriological Proceedings, 1969.

(7223)

SCALE EFFECTS OF MACROMOLECULES ON CAVITATION.

- (c) J. G. Waugh, Code 2540.
- (d) Experimental; applied research.
- (e) The purpose of this program is to study theoretically and experimentally the scale effects of macromolecules on cavitation.
- (g) Experiments were carried out in the blow-down water tunnel to study the effect of dilute aqueous polymer solutions on flow-generated cavitation inception. These included Polyox WSR-301 (20, 32, 50, and 100 ppm), guar gum JZPF (300 ppm), and Prophyridium aeruginosum algae exudate (concentration unknown). Tests were made using 1/4- and 1/2-inch diameter cylindrical models with hemisphere noses. Cavitation inception was inhibited at Reynolds numbers from 7×10^4 to 3×10^5 , and a maximum reduction of the incipient cavitation number to 50% of its value for tap water was observed. Flow visualization was obtained by optical techniques which were also used to measure fluid velocities, thereby providing a check on values obtained from the Venturi pressure drops. Possible mechanisms to explain cavitation inhibition are being investigated, and further studies will be conducted.

(7224)

DISPERSION OF OCEAN CONTAMINANTS.

- (b) Director, Division of Reactor Development and Technology, AEG.
- (c) W. A. Middleton, Code 2542.
- (d) Theoretical; applied research.
- (e) Main objective of the program is to develop a mathematical model to estimate contaminant dispersion in an ocean environment with the boundaries present, e.g., estuaries and near-shore regions. The isopleths are desired under realistic conditions of flow.
- (g) The model compares favorably with surface/near surface experiments. Eddy cell-like structures measured by investigators are also predicted analytically.

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U. S. NAVAL UNDERSEA RESEARCH AND DEVELOPMENT CENTER, San Diego, California 92132. Commander.

(6125)

ADVANCED TOWED SYSTEMS.

- (b) Naval Ship Systems Command.
- (c) C. N. Miller, Code 6021.
- (d) Theoretical and experimental.
- (e) The primary objective of the project is to develop rigorous design procedures for high-speed towed systems, through correlation of model and full-scale tests and computer simulation.
- (g) Experimental results indicate good agreement with computer simulation.

(7225)

SEAWATER HYDRAULIC TOOLS.

- (c) R. A. Nelson, Code 6522.
- (d) Experimental; development.
- (e) The purpose of this program is to modify and test available hydraulic and pneumatic devices that show promise of adaptation to a seawater hydraulic motor.
- (g) Evaluation of selected commercial hydraulic motors is underway. Modifications are being designed.

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U. S. NAVY UNDERWATER SOUND LABORATORY, New London, Connecticut 06320. Captain Bryce D. Inman, Commanding Officer.

(6266)

HYDRODYNAMIC NOISE.

- (c) Dr. Howard H. Schloemer.
- (d) Experimental and theoretical; applied research.
- (e) Experimental investigations are being conducted in both acoustic wind and water tunnels to determine the statistical properties of boundary pressure, such as power spectrum, longitudinal and lateral cross-spectra, diagonal correlations, convection speeds and space-time correlations. This work is accomplished in both zero and mild gradients with smooth and varying degrees of wall roughness. All sensors are mounted flush to the wall. Experimental results are compared to theoretical predictions. With these studies it is hoped to be able to more completely describe the noise field produced by turbulent flow.
- (g) The effect of distributed sand grain type roughness is to increase the power spectral density, decrease the convection velocity ratio and the magnitude of the normalized longitudinal cross-spectral density of boundary layer wall pressure fluctuations. The inner portion of the boundary layer adjusts very rapidly to changes in wall

finish, i.e., smooth to rough or rough to smooth. These measurements were made in the acoustic wind tunnel.

The acoustic water tunnel was used to investigate the effects of an elastic material over the face of a flush mounted hydrophone. As the thickness of the elastic material is increased, a large reduction in the power spectral density of boundary layer wall pressure fluctuations occurs for increasing frequency. There is a limit to the thickness of the elastic material for the same surface area in reducing boundary layer pressure fluctuations.

Theoretical studies continued in the direction of understanding the flow-induced noise problem. These dealt with a comparison of turbulent-flow induced, plate-vibration statistics computed for mathematical models of finite and infinite thin plates. These comparisons show little similarity between computed turbulent-flow vibration statistics for the finite and infinite plate models. Further work was done on the effects of non-instantaneous transducer response on the measurement of boundary layer wall pressure fluctuations. Studies are continuing on the effect of heavy fluid loading on the vibration statistics of finite plates excited by turbulent flow.

- (h) "Turbulent Flow Excited Vibration of a Simply Supported Rectangular Flat Plate," W. Strawderman and R. S. Brand, J. Acoust. Soc. Am., Vol. 45, No. 1, pp. 177-192, January 1969.

"Turbulence-Induced Plate Vibration: An Evaluation of Finite and Infinite Plate Models," W. Strawderman, J. Acoust. Soc. Am., Vol. 46, No. 5 (Part 2), pp. 1294-1307, November 1969.

"Effects of Non-Instantaneous Transducer Response on the Measurement of Turbulent Pressure," W. Strawderman, J. Acoust. Soc. Am., Vol. 46, No. 5 (Part 2), pp. 1289-1293, November 1969.

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U. S. NAVAL UNDERWATER WEAPONS RESEARCH AND ENGINEERING STATION, Research Department, Oceanography Branch, Newport, Rhode Island 02840. John F. Brady, Department Head.

(7555)

OCEANOGRAPHIC TURBULENCE RESEARCH.

- (c) A. T. Massey, Research Oceanographer.
(d) Field investigation; basic research.
(e) The determination of the spatial and temporal structure of the fluctuating velocity, pressure, temperature and salinity fields associated with turbulent processes in the mixed surface layer of the ocean; the examination of the balance between the time rate of change of the energy (variance) and the rates of energy production, dissipation and diffusion for the fluctuations in velocity, temperature and salinity; the investigation of the interaction between turbulent quantities and synoptic oceanographic and meteorological variables (temperature, salinity and velocity profiles, and air-sea interface condition).

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U. S. NAVAL WEAPONS LABORATORY, Dahlgren, Virginia 22448. Mr. Bernard Smith, Technical Director.

(6427)

FLOW OF LIQUID THROUGH MULTIPLE ORIFICES.

- (6) Joint Technical Group for Munitions Effectiveness.
(c) Dr. William G. Soper, Research Associate, Code GR.
(d) Experimental and theoretical; applied research.

- (e) The project objective is a mathematical model for predicting the leakage rate for a liquid container with an arbitrary number of perforations of arbitrary size and shape.
(f) Completed.

- (g) A simple model, incorporating two empirical curves, has given good results for gasoline, water, and diesel fuel, and for circular and rectangular orifices.

- (h) "Flow of Liquid Through Multiple Orifices," W. G. Soper, Naval Weapons Lab. Tech. Memo. No. T-11/67, Sept. 1967 (copies available from DDC).

(7073)

ENTRY PROBLEM FOR BLUNT WEDGES AND CONES.

- (c) Dr. William G. Soper, Research Associate, Code GR.
(d) Theoretical; applied research.
(e) Solutions are to be obtained for the flow fields around blunt wedges and cones entering a compressible fluid half-space. Results will be applied to the design of penetrating projectiles.
(g) The governing equation has been found to be a non-linear, second-order, elliptic partial differential equation in two similarity variables. Approximate numerical solutions for the wedge have been obtained.

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U. S. NAVY WEATHER RESEARCH FACILITY, Building R-48, Naval Air Station, Norfolk, Virginia 23511. Captain W. L. Somervell, Jr., USN, Commanding Officer.

(6474)

AIR-SEA INTERACTIONS.

- (b) Naval Air Systems Command.
(d) Applied research.
(e) A study of air-sea interactions of significance to the prediction of atmospheric effects upon variations in the surface-mixed layer, and of oceanic effects upon maritime weather phenomena.
(h) "Microphysical and Chemical Aspects of Sea Fog and Oceanic Haze," NWR 43-0168-134.
"Numerical Simulation of Supercooled Fog Dispersion," NAVWEARSCHFAC Tech. Paper No. 4-68.
"An Engineering Study of Potential Warm Fog Dispersion Techniques," NAVWEARSCHFAC Tech. Paper No. 1-69.
"A Proposal for Establishment of the Navy Air-Ocean Research Center (AIROCEANRSCHCN)," NAVWEARSCHFAC Tech. Paper No. 14-69.
"Engineering Fog-Modification Experiments by Computer Modeling," NAVWEARSCHFAC Tech. Paper No. 1-70.
"Example of Surface Interaction Calculations Over the Gulf of Tonkin," NAVWEARSCHFAC Tech. Paper No. 7-69.

(6475)

EVALUATION OF SYNOPTIC OCEANOGRAPHIC ANALYSES.

- (b) Naval Air Systems Command.
(d) Applied research.
(e) A study to determine the scale at which synoptic analysis (hence operational prediction) of oceanographic surface and mixed-layer thermal features is feasible, and to resolve therefrom differences among analytical procedures currently employed operationally.
(h) "Analysis and Forecasting of Sea-Surface Temperature (SST)," NWR 36-0667-126.
"Synoptic Analysis and Forecasting of Surface Currents," NWR 36-0667-127.
"Analysis and Prediction of the Depth of the Thermocline and Near-Surface Thermal Structure," NWR 36-0667-128.

- (6476)
SEA, SWELL, AND SURF PREDICTION AND CLIMATOLOGY.
(b) Naval Air Systems Command.
(c) Applied research.
(e) Research to resolve discrepancies between operational observations of sea, swell, and surf and characteristics derived from existing wave/surf development/decay theories; to develop improved objective operational techniques for sea, swell and surf prediction, to include emphasis on enclosed seas; and to prepare improved wave and surf climatologies for planning purposes from historical wind field analyses.

- (6477)
STORM SURGE.
(b) Naval Air Systems Command.
(d) Applied research.
(e) A study of methods for objective prediction of storm surges, and the development of a computer program for their issuance.
(h) "Storm-Surge Forecasting," NWRP 36-0668-138.

- (7074)
EFFECTS OF THE OCEAN THERMAL STRUCTURE ON TROPICAL CYCLONES AND VICE VERSA.
(b) Naval Air Systems Command.
(d) Applied research.
(e) Research to determine the influence of the ocean environment on intensification or dissipation and the movement of tropical cyclones, as well as determine the changes caused by tropical cyclones on the ocean environment.

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TENNESSEE VALLEY AUTHORITY, Engineering Laboratory,
Drawer E, Norris, Tennessee 37828. Rex A. Elder,
Laboratory Director.

- (4881)
BASIC STREAM HEAT BUDGET STUDIES.
(d) Experimental; for basic and applied research.
(e) This is a study to develop the basic temperature prediction equations for a stream into which water at a temperature other than natural temperature flows. All known variables such as stream flow characteristics will be included. Theoretical studies, field tests, and possible laboratory studies will be combined to produce verified equations.
(g) As a first step, solutions for fully mixed conditions have been obtained, involving the equilibrium temperature concept, from the basic set of differential equations governing water and heat flow in open channels. An intensive study of individual heat budget terms has been made to determine proper computational methods. Five sets of field data have been collected for checking the accuracy of the prediction equations.
(h) Internal reports, papers, and discussions:
"Heat and Mass Transfer Between a Water Surface and the Atmosphere," Lab. Rept. No. 14.
"Water Temperature Regime of Fully-Mixed Streams," Lab. Rept. No. 15.
"The Computation of Daily Mean Stream Temperatures," Advance Rept. No. 11.
Discussion, "Analyzing Steam Electric Power Plant Discharges."
*Presented at the ASCE Hydraulics Div. Specialty Conf., Logan, Utah, August 1969.

- (5392)
MODEL FLUME TO BE USED TO STUDY THERMAL DENSITY RECIRCULATION PROBLEMS.
(d) Experimental; operations and basic research.

- (e) A model flume was constructed of transparent material and equipped with circulating pumps to simulate a typical steam power plant's condensate intake and outlet system. The flume is approximately 100 feet in length and 9 inches deep by 12 inches wide. The basic intent is to develop and prove the analytical equations for flows in the vicinity of a steam plant or in similar areas.
(g) Data on lengths and depths of warm wedges near the intake and outlet, for various river and intake flows and for various intake density differences have been obtained, but have not been analyzed.

- (6712)
WATER QUALITY STUDY -- HYDRODYNAMICS OF A DENSITY-STRATIFIED RESERVOIR.
(d) Field investigation; basic research.
(e) Effective and optimum water resource development requires knowledge of the yearly cyclic changes of the various properties of the water in deep, stratified reservoirs. Dissolved oxygen content, temperature conductivity and density as a function of depth were measured at various stations in Fontana Reservoir and in its inflows and outflows during 1966. Current velocities were measured from a securely moored barge with a deep water isotopic current analyzer which is capable of measuring velocities of 0.005 ft/sec.
(f) Data evaluation and analysis are in progress.
(h) "Evaluation of Fontana Reservoir Field Measurements," Walter O. Wunderlich and Rex A. Elder, Proc. ASCE Specialty Research Conf. on Current Research into the Effects of Reservoirs on Water Quality, Dept. of Sanitary and Water Resource Engrg., Vanderbilt Univ., Nashville, Tennessee.
"Intake Elevation and Operation on Water Temperature," Walter O. Wunderlich and Rex A. Elder, J. Hyd. Div., ASCE, Vol. 95, No. HY6, Proc. Paper 6917, November 1969.
"Cherokee Reservoir -- Selective Withdrawal," Laboratory Report No. 13.

- (6715)
BROWNS FERRY PROJECT -- CONDENSER COOLING WATER DIFFUSER.
(d) Applied research.
(e) The heated condenser cooling water from the nuclear powered generating station is to discharge into Wheeler Reservoir through a diffusing structure so as to mix the heated water with the flowing reservoir water and to limit the temperature rise in the reservoir. The mixing structure consists of three large corrugated steel pipes with multiple small side ports, laid on the bottom across the reservoir. The heated discharge jets through the ports and is mixed with the cooler river water due to the turbulent jet action of the buoyant plume. A model study was conducted to obtain discharge coefficients for the small side ports in the corrugated wall, and a digital computer study was made to iterate the hydraulic equations for flow through the pipe such that uniform port discharge could be obtained for a specified total head.
(f) Completed.
(g) Information was obtained for the design of the diffuser pipes, i.e., the pipe diameters and lengths. The port diameter and spacing and number of ports were decided.
(h) "Internal Hydraulics of Thermal Discharge Diffusers," Svein Vigander, Rex A Elder, and Norman H. Brooks, J. Hyd. Div., ASCE, Vol. 96, HY2, Proc. Paper 7085, February 1970.

- (6716)
WHEELER PROJECT -- UNITS 9-11 VIBRATION STUDIES.
- (d) Field investigation.
 - (e) The three new 35 MW fixed-blade propeller hydro-turbines at Wheeler Dam vibrate excessively at certain gate openings. One of the units was instrumented with pressure and strain gages and tests were conducted in an effort to isolate the causes. Additional tests on one of the units were made to measure generator and turbine guide bearing loads, thrust bearing loads, forces transmitted to the structure, displacements and stresses in the supporting concrete structure, turbine blade stresses, turbine shaft stresses, and generator spider arm stresses.
 - (g) Results indicate that all the measured stresses are below the yield and endurance limits for the various materials.
 - (h) One internal report was issued.
- (6718)
BEAR CREEK PROJECT -- SPILLWAY.
- (d) Experimental; for design.
 - (e) An emergency chute spillway will be provided for flows in excess of the intake structure capacity. A 1:100 scale model was used to develop the wall layout which would minimize flow depths and standing waves in the chute, to check the spillway capacity, and to determine erosion tendencies downstream from the chute.
 - (f) Completed.
 - (g) Tests were conducted using a sand-cement mixture simulating bedrock, to determine the degree of undermining of the lower spillway at high discharges. A dike along the right side of the stilling basin and extension of a cutoff wall at the end sill were the best means found to bring the undermining action under control.
 - (h) Six internal reports were issued.
- (6719)
FIXED CONE DISPERSION VALVES -- CONTAINMENT STRUCTURE.
- (d) Experimental; applied research.
 - (e) Numerous future projects will have a fixed-cone dispersion valve located at the end of a tunnel. To confine the flow from the valve to a limited area, the valves will discharge into a structure. This structure must produce good flow distribution so as to produce acceptable downstream scour without interfering with the re-aeration capability of the valves. If possible, one basic structure geometry will be used for a wide variety of valve sizes and operating heads.
 - (f) Complete.
 - (g) A structure meeting the above objectives was developed by means of model studies. To assist in the re-aeration of water, the structure developed was of the free-discharge type, producing a re-orientation of the flow rather than energy dissipation. The geometry of the structure, as well as such hydraulic characteristics as the flow impact area and maximum wave heights and velocities in a recommended downstream channel, are given in terms of the valve diameter.
 - (h) "A Basic Howell-Bunger Valve Containment Structure," Rex A. Elder, George E. Hecker, and Marvin N. Smith, presented at ASCE Natl. Mtg. Water Resources Engrg., Feb. 1969, New Orleans, La.
- (6723)
RACCOON MOUNTAIN PUMPED-STORAGE PROJECT -- INTAKE-OUTLET IN UPPER RESERVOIR.
- (d) Experimental; for design.
 - (e) A scale model of the upper reservoir will be used to reproduce the upper Raccoon Mountain Reservoir. A morning glory structure is contemplated for the reservoir intake-outlet. The model will be used to study flow patterns at the intake-outlet during the turbine operating mode. Special attention will be given to the occurrence of vortices and their effect on setting a minimum pool elevation.
 - (f) Model design and construction under way.
- (6729)
AERATION CHARACTERISTICS OF FIXED-CONE DISPERSION HOWELL-BUNGER VALVES.
- (d) Field investigation; applied basic research.
 - (e) Tests were initiated to investigate the aeration characteristics of fixed-cone dispersion Howell-Bunger valves when discharging water having low dissolved oxygen concentrations. A field test facility was constructed at Nottely Dam in North Georgia where low DO water supply is available during July, August, and September. Two valve sizes were used: 24-inch and 12-inch diameter. The test program was divided into three phases: (1) free discharge into the atmosphere; (2) discharge into a containment structure; and (3) discharge into a tunnel. DO concentrations are measured upstream from the valve, and from the containment area downstream from the valve.
 - (f) Suspended.
 - (g) Field tests were conducted on phases 1 and 2 only. Those studies showed the fixed-cone dispersion valve to be an effective aeration device.
 - (h) A progress report, "Aeration Efficiency of Howell-Bunger Valves," was published.
- (7075)
FIXED-CONE DISPERSION VALVES -- DISCHARGE RATING AT WATAUGA DAM FOR LOW DISCHARGES.
- (d) Field investigation; for operations.
 - (e) In conjunction with USGS, field tests were conducted at the dam to establish discharge ratings for the two Howell-Bunger valves at the dam at discharges of 40 to 200 cfs.
 - (f) Completed.
- (7076)
TOLLOVE PROJECT -- SPILLWAY DISCHARGE RATING CURVES AND TABLES.
- (d) Applied research; for operations.
 - (e) 1:72-scale model tests were conducted to develop a spillway discharge rating table. The model duplicated the entire spillway. Tests were run for flows over the spillway crest and with the spillway gates at various gate opening positions for free and submerged flow conditions.
 - (f) Suspended; a spillway discharge rating table, giving specified gate position arrangements, will be prepared.
- (7077)
LITTLE BEAR CREEK PROJECT -- SPILLWAY CHUTE DESIGN.
- (d) Applied research; for design.
 - (e) A 1:36-scale model of the proposed spillway and chute design was used to develop an acceptable scheme to fulfill the requirements of flow capacity, wave heights, and velocities in the downstream basin.
 - (f) Completed.
 - (g) A quadruple-slot spillway design was developed which would carry the required flows.
 - (h) Nine internal reports were issued.
- (7078)
LITTLE BEAR CREEK PROJECT -- FIXED-CONE DISPERSION VALVE DESIGN.
- (d) Applied research; for design.
 - (e) Tests were conducted, using a 1:15-scale model of a low-level discharge structure, to develop channel dimensions and limiting conditions for satis-

factory operation of a proposed 5-foot diameter fixed-cone dispersion Howell-Bunger valve at this project.

- (f) Completed.
- (g) A containment structure with downstream channel dimensions and limiting conditions for satisfactory operation were developed for the adaptation of the Howell-Bunger valve installation.
- (h) One internal report issued.

(7079)

KENTUCKY PROJECT -- REVISED SPILLWAY GATE OPENING SEQUENCE TO ELIMINATE EROSION ACTION.

- (d) Applied research; for operations.
- (e) A 1:100-scale model of Kentucky Dam, duplicating the entire spillway, powerhouse and approximately 5000 of the downstream river channel was used to develop a spillway gate opening sequence which would eliminate serious erosive action caused by the backflow of gravel onto the spillway apron.
- (f) Completed.
- (g) A revised spillway gate opening schedule was developed and put into immediate use.

(7080)

RACCOON MOUNTAIN PUMPED-STORAGE PROJECT -- HYDRAULIC TRANSIENT STUDIES.

- (d) Applied research; for design.
- (e) A complete mathematical model of the Raccoon Mountain pumped-storage system was developed to study the system transients. The model provided options for surge chambers on either side of the pump-turbines and the capability of revealing cavity formation and growth in the upper and lower conduits. The model also permitted the study of effects from changes in upper and lower pool levels, conduit geometry, conduit resistance, machine characteristics, number of machines, surge chamber geometry, and valve and/or wicket gate movements.
- (g) Two internal reports were issued containing findings from these studies.

(7081)

RACCOON MOUNTAIN PUMPED-STORAGE PROJECT -- INTAKE-OUTLET IN LOWER RESERVOIR.

- (d) Applied research; for design.
- (e) A 1:90-scale model of Nickajack Reservoir is being used to develop a structure which will permit discharge and withdrawal from Nickajack Reservoir without adversely affecting navigation. A unique feature of the model is the digital computer control which allows it to monitor or measure flow rates, and change direction of any or all flows in the model to generate the hydrographs which will be expected.

(7082)

BROWNS FERRY NUCLEAR PLANT -- HYDRODYNAMIC FORCES ON SUBMERGED DIFFUSER PIPES.

- (d) Applied research; for design.
- (e) Condenser cooling water from the Browns Ferry Nuclear Plant will be mixed with the flow in Wheeler Reservoir by means of three large diameter (20.5, 19, and 17-foot) corrugated metal pipes, half buried across the main navigation channel of the reservoir. To design adequate anchorages for these diffusers, laboratory investigations were undertaken to measure the hydrodynamic forces existing on these diffusers. Forces resulting from flood flows and forces resulting from the passage of barge trains over the diffusers were measured. The effect of flood flows was determined by measuring lift and drag coefficients over a range of Reynolds numbers for various pipe and backfill configurations. The effect of barge trains was

determined by constructing a towing tank 140-feet long by 35-feet wide; and towing a 1:20-scale barge train over a diffuser of the same scale instrumented to measure vertical and horizontal forces. Variables in these tests include: towing speed, length and width of barge train, reservoir depth, and flow velocity. These tests indicated that forces resulting from barge trains were considerably greater than forces from flood flows, possibly as high as 10,000 to 15,000 pounds per foot of pipe depending upon the type of backfill material used. Further evaluation is under way on the effects of backfill material on anchorage requirements. A test facility is utilized in which pipes, which are half buried in selected backfill materials, are subjected to forcing functions as determined from the towing tank tests.

(7083)

BROWNS FERRY NUCLEAR PLANT -- CONDENSER-WATER THERMAL DIFFUSION IN A THREE-DIMENSIONAL MODEL.

- (d) Applied research; for design.
- (e) Condenser cooling water from the Browns Ferry Nuclear Plant will be mixed with the flow in Wheeler Reservoir by means of three diffuser pipes. Flow through Wheeler Reservoir is controlled by two hydro-projects -- Wheeler and Guntersville Dams. These projects are operated for peaking power purposes and, as a result, flows in Wheeler Reservoir are highly variable. To evaluate the effects of operations of these two hydro-projects and Browns Ferry on the thermal regime of Wheeler Reservoir, a distorted scale model, 1:250 horizontal and 1:50 vertical, will be constructed. Operation of the model will be under control of a digital computer and will be capable of simulating both steady and unsteady flows. Three hundred thermistors connected to the computer through a crossbar scanner will be used to collect and analyze temperature data.
- (f) Model design nearly complete.

(7084)

SEQUOYAH NUCLEAR PLANT -- CONDENSER COOLING WATER DIFFUSER STUDY.

- (d) Applied research; for design.
- (e) The Sequoyah Nuclear Plant, located on Chickamauga Reservoir, will have a two-unit capacity of 2600 MW. The condensers for this plant are designed for a flow of 1244 cfs per unit and a temperature rise of about 29°F. To satisfy temperature criteria, diffusers will be used to mix the condenser cooling water with reservoir water. It is anticipated that the diffusers will be in conjunction with an underwater dam to reduce the thickness of the upstream warm water wedge, thereby, reducing the size of a proposed intake skimmer wall. Both concrete pipe and corrugated metal pipe will be considered for use as diffuser pipes.
- (h) One internal report has been issued.

(7085)

CUMBERLAND STEAM PLANT -- SKIMMER WALL AND INTAKE CHANNEL STUDIES.

- (d) Applied research; for design.
- (e) Studies were conducted, using a 1:100 scale model of a proposed skimmer wall and condenser water intake channel for the Cumberland Steam Plant. The effects of river velocity and intake channel shape on the flow distribution under the skimmer wall were investigated.
- (f) Completed.
- (g) Minimum skimmer wall length, maximum river bed elevation in front of the skimmer wall, minimum total opening between skimmer wall cells and acceptable channel widths and slopes were developed.

(h) Three internal reports were issued.

(7086)

CUMBERLAND STEAM PLANT -- CONDENSER COOLING WATER DISCHARGE CANAL AND FLOW DISTRIBUTION STRUCTURE.

(d) Applied research; for design.

(e) Tests were conducted using a 1:55-scale model to determine the appropriate discharge canal geometry which would minimize mixing of the discharged waters with the reservoir waters. An examination was made of the effects of: seasonal water temperature variations, reservoir elevation changes, Cumberland River discharge, and a reduction in condenser cooling water flows to one-third of the proposed two-unit design.

(f) Completed.

(g) A discharge canal geometry which would perform satisfactorily when the distribution of flow was uniform through the cross-section of the canal. A flow distribution structure and its location in the canal were recommended.

(h) Two internal reports were issued.

(7087)

FIXED-CONE DISPERSION VALVE -- CONTAINMENT STRUCTURE FOR DISCHARGE INTO A TUNNEL.

(d) Experimental; applied research.

(e) After a literature search, a model was constructed to test the energy-dissipation characteristics of a 4-inch Howell-Bunger valve discharging into a tunnel.

(f) Complete.

(g) A structure was developed, by means of a model study, for Howell-Bunger valves mounted with their longitudinal axes horizontal and discharging into a structure of oval-shaped cross-section. Low-head applications were tested, with head to valve diameter ratios from 12 to 25. The developed oval-section height and width is about 5 and 3 valve diameters, respectively. Total structure length is 9 valve diameters. A deflector ring mounted around the inside of the section aids in the dissipation of kinetic energy in the flow. Observation of the model performance indicates the aeration qualities of the valve are not reduced.

(h) "Structure for a Howell-Bunger Valve in a Tunnel," Marvin N. Smith, presented at ASCE National Water Resources Engrg. Meeting, Memphis, Tennessee, January 26-30, 1970.

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TENNESSEE VALLEY AUTHORITY, Hydraulic Data Branch, Knoxville, Tennessee 37902. Paul C. Spath, Branch Chief.

(765)

EVAPORATION IN THE TENNESSEE BASIN.

(d) Field investigation; applied research.

(e) To provide data for estimating reservoir losses and derive a general rule, applicable to the Basin, permitting computation of evaporation from pans at six locations in Basin, together with standard meteorological readings.

(h) Results published in monthly and annual bulletins, "Precipitation in Tennessee River Basin" (Project 768).

(768)

PRECIPITATION IN TENNESSEE RIVER BASIN.

(d) Field investigation; basic research.

(e) A comprehensive study of rainfall and other weather phenomena for purposes of water dispatching and improvements in water control; storm studies as related to maximum precipitation,

rainfall-runoff, spillway design and operation, etc.

(h) Monthly and annual bulletins, "Precipitation in Tennessee River Basin."

(769)

RESERVOIR AND STREAM TEMPERATURES.

(d) Field investigation; basic research.

(e) Study of water utilization and water movement as concerns industrial and steam plant locations and stream pollution. Variations in temperature from surface to bottom in selected reservoirs are determined by soundings, and by continuous recording gages in selected natural streams. Periodic observations are made at gaging stations.

(771)

GALLERY DRAINAGE IN LARGE DAMS.

(d) Field investigations; design.

(e) Weirs are placed in main galleries and drainage measured as check on tightness and stability.

(779)

MAXIMUM POSSIBLE PRECIPITATION IN TENNESSEE VALLEY.

(b) Cooperative with U. S. Weather Bureau.

(d) Theoretical; applied research.

(e) Hydrometeorological analysis of large storms with upward adjustments of controlling factors to maximum limits as applied to the Tennessee Valley and subdivisions.

(h) "Probable Maximum and TVA Precipitation for Tennessee River Basins Up to 3000 Square Miles in Area and Durations to 72 Hours," Hydrometeorological Report No. 45, U. S. Weather Bureau, May 1969.

(780)

PERIODIC EVALUATION OF GROUND-WATER STORAGE.

(d) Theoretical; operation.

(e) By analysis of current records of stream discharge, the volumes of runoff in ground water and channel storage are determined for use in operation of multipurpose reservoirs.

(g) Results reported weekly within the organization.

(785)

SEDIMENTATION OF EXISTING RESERVOIRS.

(d) Field investigation; design and operation.

(e) Selected ranges in reservoirs are probed and sounded, volumetric samples are collected and analyzed, quantity and distribution of sediment are computed to determine deposition by stream, probable life of reservoir, effect of sediment storage on navigation channels and sedimentation of downstream reservoirs, and probable sedimentation in future reservoirs.

(h) "Sedimentation in TVA Reservoirs," Rept. No. 0-6693, Tennessee Valley Authority, Knoxville, Tenn., February 1968.

(3306)

COOPERATIVE RESEARCH PROJECT IN WESTERN NORTH CAROLINA.

(b) Project conducted in cooperation with North Carolina State University.

(d) Field investigation; basic research.

(e) To determine water-plant-soil relationship on some of the principal soils used for agricultural purposes in western North Carolina under important vegetative covers. Four crops are rotated on four small watersheds under a "Latin-Square" statistical design. Observations include rainfall, runoff, groundwater levels, soil moisture, evaporation, potential and actual evapotranspiration.

(f) Fieldwork completed.

(g) Results will be published in final project report

to be completed July 1, 1970.

(3308)
WHITE HOLLOW WATERSHED.

- (d) To study the effect of changes in the vegetal cover on a watershed taken out of cultivation on the hydrologic factors of runoff and soil erosion.
- (e) Continuous record from 1935 of rainfall, runoff, and suspended sediment, and periodic determination of vegetal cover indexes.
- (f) Selected pulpwood cutting completed in 1966, and sawtimber cutting completed in 1968.
- (g) During the 24-year period 1935-1958, the forest cover improvement in the watershed resulted in greater watershed protection with no measurable change in water yield, no change in volume of either surface runoff or groundwater runoff, marked reduction in summer peak rates of discharge with lesser reduction in winter rates, a prolongation of the period of draining of surface runoff from the channel system, and a 96 percent reduction in the sediment load.

(3309)
PINE TREE BRANCH WATERSHED.

- (d) To determine the effects upon the hydrology of the watershed by reforestation and erosion control measures.
- (e) Continuous record from 1941 of rainfall, runoff, groundwater, and sediment loads.
- (f) Selected pulpwood cutting completed in 1966. Watershed reinventoried.
- (g) During the 20-year period 1941-1960, the cover improvement and erosion control in the watershed resulted in a decrease in surface runoff volumes and an increase in groundwater discharges, marked reductions in summer and winter peak flood discharges, a reduction in overland surface velocities, a prolongation of the period of draining of surface runoff from the channel system, an appreciable decrease in water yield, and a 96 percent reduction in sediment load.

(4011)
NORTH FORK CITICO CREEK RESEARCH WATERSHED.

- (b) Project conducted in cooperation with U. S. Forest Service and Tennessee Game and Fish Commission.
- (d) Field investigation; basic research.
- (e) To determine the effects of normal, high-standard National Forest multiple-use management upon the hydrology of the area. Observations include rainfall, runoff, air and water temperature, and humidity. Timber inventories, soil surveys, wildlife inventories, and evaluations of soil disturbances will be made. Project activities are divided into calibration, development, and evaluation phases.
- (f) Calibration period completed. Action phase began with access road to first timber sale area and completion of sale in fall of 1969.
- (g) Results are published in annual reports distributed to cooperating agencies.
- (h) "North Fork Citico Creek Watershed Study," Annual Water Year Reports 1961-69, Tennessee Valley Authority, U. S. Forest Service, and Tennessee Game and Fish Commission.

(4884)
UPPER BEAR CREEK EXPERIMENTAL PROJECT.

- (b) TVA Tributary Area Development project cooperative with U. S. Forest Service and Auburn University.
- (e) Quantitative determination of the effect of soil type, slope, and vegetative cover upon runoff, peak discharge, and erosion on small watershed progressing to large watersheds. Development

of procedures to make data usable in projecting effects from small watersheds to larger drainage areas and to transfer results of the study to ungaged areas.

- Four general types of land cover and use will be considered in the study of the watersheds that progress downstream from areas of several hundred acres through intermediate-sized watersheds to a drainage area of 143 square miles.
- (f) Hydrologic conditions surveys made in March, August, and November 1967, and March 1969. Bacteriological sampling at selected stations February 1965 to May 1966. Clear cutting of all merchantable timber on one small watershed completed in spring of 1969.
- (g) Results are published in quarterly and special reports on the subject.
- (h) "The Upper Bear Creek Experimental Project," 1965-67, TVA, U. S. Forest Service, May 1968.

(7088)
COAL STRIP-MINE WATERSHED DEMONSTRATION, JACKSON COUNTY, ALABAMA.

- (d) Field investigation; basic research.
- (e) To determine the effects of coal strip-mining and subsequent reclamation upon the hydrologic response, water quality, and stream ecology of a small watershed. Observations include rainfall, runoff, sediment, water temperature, water quality, and stream ecology.
- (f) Project began in 1968 with the installation of a weir and recording equipment for collection of basic data.
- (g) Reports to be prepared upon completion of the mining phase and then 5 and 10 years thereafter.

(7089)
WATERSHED STUDIES OF FERTILIZER MOVEMENT.

- (d) Field investigation; basic research.
- (e) The relationship between the fertilization of agricultural and forested lands and the chemical composition of runoff will be studied in several watersheds in the Tennessee Valley. This will include instrumented watersheds, now being utilized for other purposes, which will be modified to permit the sampling required for this study.
- (f) One watershed has been instrumented, and records of rainfall, streamflow, and water quality began in 1969. An initial calibration period will be conducted prior to fertilization. Small grass plots will be protected from grazing and the forage sampled several times during the growing season to obtain data on the recovery of applied fertilizer constituents by pasture grasses under study.
- Data collection on two small agricultural watersheds and on three forested watersheds, already instrumented for other research, was expanded to include water-sampling programs to provide information on nutrient content of runoff. Subsequent fertilization of the watersheds will be coordinated with proposed management programs.
- (g) Findings resulting from this research will be published in technical journals and project reports.

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U. S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY
ADMINISTRATION, Office of Research, Environmental
Design and Control Division, Hydraulics and Hydrology
Specialty Group, 4200 Connecticut Avenue, N. W.,
Washington, D. C. 20591. Dr. Homer W. Parker,
Leader.

For summaries of the following projects, refer
to Water Resources Research Catalog:

(080W)

INVESTIGATION OF RAINFALL DISTRIBUTION ON URBAN RUN-
OFF FOR IMPERVIOUS AREAS.

Volume 4, 2.0306.

(086W)

DEVELOPMENT OF HYDRAULIC DESIGN PROCEDURES FOR STRUC-
TURAL PLATE PIPE AND PIPE-ARCH CULVERTS USING RESIS-
TANCE FACTORS FROM RECENT RESEARCH.

(c) J. M. Normann.

Volume 4, 8.0159.

(7218)

ANALYTICAL STUDY OF HYDRAULICS OF BRIDGE WATERWAYS.

(d) Experimental; applied research.

(e) A model flume 182.5 feet long and 22.7 feet wide
is under construction for analytical study of
hydraulics of bridge waterways. The objective of
the study is to develop methods for analysis of
the hydraulic factors causing bridge backwater
and local velocities of flow conducive to scour
at piers and abutments and to devise laboratory
models for verification of the analyses.

UNIVERSITY OF ALBERTA, Department of Civil Engineering,
Edmonton 7, Alberta, CANADA. Dr. T. Blench,
Professor.

(6630)

ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

- (b) T. Blench and Associates, Ltd.
- (d) Applied research.
- (e) Text collating field and laboratory research by regime theory principles to answer major problems of "Evolution of River Bed" and related portion of "Influence of Man on Continental Waters." Problems outlined in UNESCO Note NS/NR/17 dated Paris 15th October 1962 in anticipation of International Hydrologic Decade.
- (f) To be revised periodically.
- (h) "Mobile-Bed Fluviology," 2nd Revised Ed., 1969. Univ. of Alberta Press. 14 chapters, 33 photos, 31 diagrams, 25 worked problems.

(6884)

ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

- (b) University on NRC Grant.
- (d) Lab study; Master's thesis; basic.
- (e) Supplement analysis of world flume-transport data at Ph.D. level.
- (f) Completed.
- (g) Primary graphic analysis of phase behaviour of bed-factor at very small transport rates, using dimensionless regime-theory parameters.
- (h) "Analysis of Bed-Load Transport in Flumes," Fazul A. Z. M. Roque. Master's thesis, University of Alberta, 1968.

(6885)

PIPE-LINE TRANSPORT OF CAPSULES.

- (b) Alberta Research Council.
- (d) Lab study; Master's thesis; basic.
- (e) In connection with joint Alberta Research Council and industrial development of practical capsule transport in pipe lines.
- (g) Mechanism of transport was clarified and theories of transport were considered and tested.
- (h) "Pipe-Line Transport of Capsules," R. T. Liddle, Master's thesis, University of Alberta, 1968.

(6886)

DIFFUSION BELOW SUBMERGED RECTANGULAR OUTLETS.

- (b) University on NRC Grant.
- (c) Dr. N. Rajaratnam.
- (d) Basic research; experimental.
- (e) To study the effects of drop and sudden expansion and eccentricity with respect to the centre line of the downstream channel of part width rectangular channels.
- (g) It has been found that after a certain distance from the reattachment line the velocity distribution is similar and agrees with classical wall jet. Variation of velocity and length scales has been studied. The centre line bed shear stress variation has been represented by a single similarity curve. Even when the eccentricity of the rectangular part-width outlet is large, the centre line velocity distribution, velocity and length scales are comparable to the corresponding classical wall jet. Similarity curves have been developed for the bed shear distribution in lateral direction. Shear stress contours are shown indicating the intensity of attack in different regions.
- (h) "Diffusion Below Submerged Rectangular Outlets," N. Rajaratnam and D. Muralidhar, J. Hydraulic Res., No. 2, 1969.

(6887)

EFFECT OF SIDE WALLS ON PLANE TURBULENT WALL JETS.

- (b) University on NRC Grant.
- (c) Dr. N. Rajaratnam.
- (d) Basic research; experimental.
- (e) To study the effect of side walls on the behaviour of plane turbulent water wall jet produced by a deeply submerged sluice gate in a rectangular channel.
- (g) It was found that the transverse velocity distribution, even very close to the side walls, is similar and agrees with that of plane turbulent wall jet under zero pressure gradient. The length scale was found to become large in the vicinity of walls and wall jet appears to climb the side walls. Some observations on the distribution of discharge intensity in the forward flow were also made.
- (h) "Effect of Side Walls on Plane Turbulent Wall Jets," N. Rajaratnam, J. Hydraulic Res., No. 4, 1968.

(6888)

FLOW BELOW DEEPLY SUBMERGED RECTANGULAR WEIRS.

- (b) University on NRC Grant.
- (c) Dr. N. Rajaratnam.
- (d) Basic research; experimental.
- (e) To study the mechanics of flow downstream of submerged sharp crested rectangular weirs.
- (g) For submergence greater than 90% the vena contracta was located. The flow is divided into initial potential core and a fully developed region. In the fully developed region flow picture was analysed and found to be same as a half turbulent free jet. Flow development region was analysed treating it as a free jet boundary problem. Standing eddy was studied using dimensional analysis. A simple discharge equation has been developed.
- (h) "Flow Below Deeply Submerged Rectangular Weirs," N. Rajaratnam and D. Muralidhar, J. Hydraulic Res., No. 3, 1969.

(6889)

SUBMERGED NON-RECTANGULAR OUTLETS.

- (b) University on NRC Grant.
- (c) Dr. N. Rajaratnam.
- (d) Basic research; experimental.
- (e) To study the diffusion below certain non-rectangular outlets under submerged flow conditions.
- (g) It has been found that in general the velocity distribution in the center plane agrees with that of the classical wall jet. The velocity and length scales are compared with that of the water wall jet. It was also found that for the non-rectangular outlets studied, the ratio of the average to maximum velocity at the efflux section is about 0.84.
- (h) "Submerged Non-Rectangular Outlets," N. Rajaratnam and D. Muralidhar, La Houille Blanche, No. 1, 1969.

(6890)

REATTACHED WALL JETS.

- (b) University on NRC Grant.
- (c) Dr. N. Rajaratnam.
- (d) Basic research; experimental.
- (e) To study the diffusion of submerged rectangular outlets, when there is a drop in the bed after some distance from the outlet.
- (g) It has been found that the length of the eddy region below the drop is not affected appreciably by the nature of the velocity distribution existing before drop. The velocity distribution in the reattached jet was found to be similar to that

of a classical wall jet. Velocity and length scales and the bed shear stress in the reattached flow were also studied.

- (h) "Reattached Wall Jets," N. Rajaratnam and D. Muralidhar, La Houille Blanche, No. 4, 1968.

(6891)

YAW PROBE USED AS PRESTON TUBE.

- (b) University on NRC Grant.
(c) Dr. N. Rajaratnam.
(d) Applied research; analytical.
(e) To study usefulness of yaw probe as Preston tube to measure boundary shear stress when both magnitude and direction are unknown.
(g) It has been found that the three-tube yaw probe can be placed on the boundary and used as a Preston tube to find the bed shear stress when both magnitude and direction are unknown. The calibration results necessary for the method were also given.
(h) "Yaw Probe Used as Preston Tube," N. Rajaratnam and D. Muralidhar, Aeronautical J., Royal Aero. Soc., December 1968.

(6892)

THE SCREW-DRIVER PROBE.

- (b) University on NRC Grant.
(c) Dr. N. Rajaratnam.
(d) Applied research; experimental.
(e) To measure static pressure in two- and three-dimensional flows with help of screw driver probes.
(g) Screw driver probes were constructed and calibrated to measure static pressure in two- and three-dimensional flows. The necessary calibration curves are developed. Limitations on the use are specified.
(h) "The Screw-Driver Probe," N. Rajaratnam and D. Muralidhar, J. Hydraulic Res., IAHR, No. 1, 1970.

(6893)

BOUNDARY SHEAR STRESS DISTRIBUTION IN RECTANGULAR OPEN CHANNELS.

- (b) University on NRC Grant.
(c) Dr. N. Rajaratnam.
(d) Basic research; experimental.
(e) To study the velocity and boundary shear stress distributions for supercritical turbulent flow in rectangular open channels.
(g) For supercritical flows with Froude number varying from 1.1 to 2.4 it was found that the velocity distribution normal to the bed and side walls agrees with the well-known Karman-Prandtl logarithmic equation except near the corners. The boundary shear stress has been correlated on the same basis as the flat plate constant pressure turbulent boundary layer. The relationship between maximum side wall and maximum bed shear stress has been studied. A preliminary analysis is made with regard to the dip in the velocity profile at the free surface.
(h) "Boundary Shear Stress Distribution in Rectangular Open Channels," N. Rajaratnam and D. Muralidhar, La Houille Blanche, No. 2, 1970.

(6894)

THE TRAPEZOIDAL FREE OVERFALL.

- (b) University on NRC Grant.
(c) Dr. N. Rajaratnam.
(d) Basic problem with practical application; theoretical and experimental.
(e) Theoretical and experimental study of the trapezoidal free overfall.
(g) Based on some assumptions the end depth ratio (EDR) has been predicted for the horizontal and

sloping overfalls. For horizontal trapezoidal free overfall, the EDR is a function of shape factor. The pressure coefficient at the end section was obtained and compared with rectangular and triangular free overfalls. For sloping trapezoidal free overfalls, the EDR is a function of shape factor and relative slope. The experimental data is compared with rectangular and triangular free overfalls. Necessary charts to predict distance for a known end depth were developed. Information regarding flow profile, velocity field and bed shear stress have also been obtained for horizontal trapezoidal free overfall.

- (h) "The Trapezoidal Free Overfall," N. Rajaratnam and D. Muralidhar, J. Hydr. Res., 8, 4, 1970, p.419.

(6895)

ROUGHNESS EFFECTS ON THE RECTANGULAR FREE OVERFALL.

- (b) University on NRC Grant.
(c) Dr. N. Rajaratnam.
(d) Basic problem with practical application; experimental.
(e) An experimental study to assess the effects of bed roughness on the end depth ratio (EDR) of the rectangular free overfall.
(g) For the horizontal free overfall, the variation of EDR with relative roughness has been evaluated. It has been found that the ratio of EDR in smooth and rough channels is same for sloping as well as the horizontal overfalls. Measurements on pressure and velocity field at the brink have been made for one wire-screen roughness.
(h) "Roughness Effects on Rectangular Free Overfall," N. Rajaratnam and D. Muralidhar (under publication).

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ATOMIC ENERGY OF CANADA LIMITED, CHALK RIVER NUCLEAR LABORATORIES, Advance Engineering Branch, Chalk River, Ontario, CANADA. H. Smedley, Branch Head.

(6896)

VIBRATION OF RODS IN PARALLEL SINGLE PHASE AND TWO PHASE FLOW.

- (d) Experimental and theoretical, basic research study.
(e) Investigation of the mechanism causing rods or rod bundles to vibrate in a fluid flowing along the rods and the amplitude of the vibration vs. flow conditions.
(g) A theory relating the amplitude of vibration to the local pressure fluctuations on the rods has been verified under a range of flow conditions.
(h) "The Role of Turbulence in the Vibration of Reactor Fuel Elements in Liquid Flow," D. J. Gorman, AECL-3371, May 1969. Obtainable through Scientific Documents Distribution Office, Atomic Energy of Canada Ltd., Chalk River, Ont., Canada.
"An Experimental and Analytical Investigation of Fuel Element Vibration in Two-Phase Parallel Flow," D. J. Gorman; submitted to Amer. Nuclear Soc. Gen. Mtg., Los Angeles, Cal., June 14-18, 1970.

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UNIVERSITY OF BRITISH COLUMBIA, Department of Civil Engineering, Hydraulics Laboratory, Vancouver 8, B.C., CANADA. Prof. W. D. Laime Finn, Department Head.

(4451)

HEAD LOSS IN SPHERICAL AND CONVENTIONAL WYES.

- (c) Dr. E. Ruus.
(d) Applied research. Much of the experimental work is being done by an M. A. Sc. student.
(e) Lucite models of spherical and conventional type of wyes were constructed and the head losses measured. For all wyes the inside diameter of

- the main pipe and the branch pipes are 5-1/4 and 3-3/4 inches, respectively. Several modifications such as tierods, tapered outlets, rounded corners and different sphere diameters are being investigated.
- (h) M. A. Sc. thesis, Hua Wang, September 1967.
- (5995)
A GENERAL-PURPOSE, LABORATORY WAVE GENERATOR.
(b) National Research Council of Canada.
(c) Professor E. S. Pretious.
(d) Design and construction of a wave generator and wave absorbers to provide laboratory facilities for wave research.
(e) The short length of the existing laboratory flumes precludes long spending beaches and also makes it necessary to generate the type of wave desired (shallow-water, deep-water or transitional type) right at the generator. By a suitable linkage the wave generator can act as a hinged paddle, a plunger, or as a combination of the two, depending on the water-particle motion desired. This wave research facility will be available for demonstration and graduate research.
(f) Completed. The same type of wave generator, with modifications and improvements, is being planned for a much larger flume in the Hydraulics Laboratory. A theoretical analysis will be made of its design and will form the subject of a thesis for a Master's degree.
(g) The results of the completed wave generator showed backlash in the gear train and beltsap in the drive when maximum acceleration of the crank occurred, which produced irregularities in the large amplitude waves. This will be remedied in the proposed new wave generator.
(h) Dept. of Civil Engrg. Rept., "A General-Purpose Wave Generator to Produce All Types of Water-Waves in Short Flumes," Prof. E. S. Pretious, July 1967.
- (5997)
RIVER FLOOD FORECASTING.
(b) British Columbia Disaster Relief Fund.
(c) Dr. M. C. Quick.
(d) Applied research (mostly theoretical).
(e) To study hydrometeorological forecasting of floods from snowmelt. This study is coupled with another study of the ripening processes within a snow pack.
(h) "River Flood Flows: Forecasts and Probabilities," M. C. Quick, Proc. ASCE, J. Hydraulics Div., Vol. 91, No. HY3, pp. 1-18, May 1965.
"A Comparison of Measured and Theoretical Snow-pack Temperatures," J. Hydrology, Vol. 5, pp. 1-20, April 1967.
- (6096)
OPTIMUM PUMP SUMP DESIGN.
(c) Dr. M. C. Quick.
(d) Experimental and theoretical; applied research.
(e) A basic investigation of vortex behaviour coupled with a study of flow patterns in sump configurations is being made. Conclusions arising from these studies are being used to develop an optimum design procedure for pump sumps.
(f) "Efficiency of Air-Entraining Vortex Formation at a Water Intake," M. C. Quick, Proc. ASCE, J. Hydr. Div., Vol. 96, HY7, July 1970, pp. 1403-1416.
Master's thesis in preparation.
- (6097)
WATER HAMMER IN IRRIGATION PIPE SYSTEMS.
(c) Dr. E. Ruus.
(d) Theoretical; applied research; for Master's thesis.
- (e) To study water hammer wave motion in irrigation pipe networks by the method of characteristics using a digital computer. In addition to pipe friction, many boundary conditions such as reservoirs, surge tanks, air chambers, sprinklers, valves, and centrifugal pump are considered. Networks up to one thousand pipes of varying diameter wall thickness and material can be handled.
(f) Completed.
(g) Very good agreement was found between results obtained from computer analyses by method of characteristics and results by the graphical method. Sprinkler discharge has a large influence in dampening of water hammer water.
(h) The findings will be presented in a Master's thesis.
- (6099)
DIMENSIONLESS RATIOS FOR SURGES IN OPEN CANALS.
(c) Dr. E. Ruus.
(d) Theoretical; for Master's thesis.
(e) To arrange the variables involved in open canal surges into groups of dimensionless ratios.
(h) The findings will be presented in a Master's thesis.
- (6100)
RIVER-BED SCOUR AT BRIDGE PIERS AND OBSTRUCTIONS.
(b) National Research Council of Canada Operating Grant.
(c) Professor E. S. Pretious.
(d) Experimental and theoretical for a Master's thesis.
(e) To find a rational expression for calculating scour of river beds at bridge piers, abutments, groin heads, piles and other obstructions, based on theory, laboratory experiments and field studies of existing local bridges.
(g) Past methods have relied heavily on empirical methods for determining scour, aided by hydraulic models.
(h) The results will be presented in a Master's thesis.
- (6985)
LAKE STRATIFICATION STUDIES.
(c) Dr. M. C. Quick and Professor S. O. Russell.
(d) Applied research.
(e) Stratification in lakes has considerable influence on lake water quality and pollution. The study has two main branches: 1. A study of destratification processes and laboratory and field estimates of the energy required to break down a known stability. 2. A study of lake currents and stratification and the distribution of nutrients and pollutants within a lake.
- (6986)
THE EFFECT OF ENTRAINED AIR IN PREVENTING CAVITATION DAMAGE BY HIGH VELOCITY FLOW.
(c) Professor S. O. Russell.
(d) Applied research.
(e) Concrete surfaces are subject to cavitation damage from high velocity flow in spillways and outlet works. Prototype evidence suggests that damage can be reduced or eliminated by entraining air in the flow. The effect of air entrainment is being investigated in an experimental open channel, three inches wide, with velocities up to 100 ft/sec.
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(6574)

UNSTEADY AERODYNAMICS OF STATIONARY ELLIPTIC CYLINDERS IN SUBCRITICAL FLOW.

- (c) Dr. V. J. Modi.
- (d) M. A. Sc. thesis.
- (e) To study unsteady forcing function and wake geometry associated with a set of elliptic cylinders, of varying eccentricity, in stationary condition.
- (g) The two-dimensional models of elliptic cylinders with eccentricity of 0.436, 0.916 and 0.98 have been tested for Strouhal frequency, unsteady loading and wake geometry in the Reynolds number range of $2 \times 10^4 - 10^5$. The visual study of the flow conditions associated with the models has been carried out using Schlieren high speed photography. The resolution of the method was found to be limited, particularly in the determination of the separation points. The flow visualization technique is being improved using birefringent fluids. The analytical determination of the separation points on the elliptic cylinders as a function of the angle of attack has been completed and the study of pressure transient decay in the wake is in progress.

(6575)

AEROELASTIC INSTABILITY OF A STRUCTURAL ANGLE.

- (c) Dr. V. J. Modi.
- (d) Ph.D. dissertation.
- (e) To study the aerodynamics and dynamics of a structural angle during vortex induced and galloping types of oscillations.
- (g) The project has investigated, experimentally, the aerodynamics and dynamics of the angle section during stationary, plunging, torsion and combined plunging-torsional conditions. The nature of the instability depends on such system parameters as damping, natural frequency, angle of attack, section size, etc. The corresponding analytical study using quasi-steady theory has been completed. The first phase of the programme has come to an end and the degree has been awarded.

(6576)

VORTEX-EXCITED OSCILLATION PHENOMENA FOR D-SECTION AND CIRCULAR CYLINDERS.

- (c) Dr. G. V. Parkinson.
- (d) M. A. Sc. thesis.
- (e) To learn more of the kinematics and dynamics of the organized vortex systems in the wake of bluff, two-dimensional bodies in the Reynolds number range $10^4 - 10^5$. In particular, the interactions between the vortex systems and elastically mounted cylinders caused to oscillate by the vortices are of interest in the region of capture of the vortex frequency by the cylinder frequency.
- (f) Completed.
- (g) Experiments have been completed, including the effect of system damping on vortex-induced oscillations of circular and D-section cylinders, and spanwise correlations of fluctuating surface pressures and wake velocities for cylinders at rest and in oscillation. A thesis was presented.

(6577)

NON-LINEAR VIBRATION IN HYDRAULIC POSITIONING SYSTEMS.

- (c) Dr. C. A. Brockley.
- (d) Ph.D. dissertation.
- (e) To investigate non-linear vibration in hydraulic positioning systems which is associated with frictional and hydraulic fluid compressibility

effects.

- (f) Completed.
- (g) A study was made of the behaviour of a hydraulically driven system subject to friction induced oscillations. An experimental apparatus consisting of a heavy mass driven by a hydraulic ram was constructed. A mathematical system model was postulated, and validated experimentally. The effects of variation in system parameters were studied on the model. It was found that leakage at the piston had negligible effects, and that the effect of piston location on system behaviour can be predicted by a stiffness correction. Parameter changes effectively change the rate of tangential load application for given average traverse velocities; this can be predicted from the proposed static friction relationship. Friction forces operating during the slip-stick process were studied. A relatively accurate relation for the static friction coefficient was found. The kinematic coefficient of friction was found to decrease gradually with the onset of slip. Both static and kinetic friction behaviour have been modeled.

(6578)

AN INVESTIGATION OF PROBLEMS OF HAEMODIALYSER DESIGN.

- (c) Dr. G. V. Parkinson, Dr. C. A. Brockley.
- (d) Ph.D. dissertation.
- (e) To investigate experimentally, supported by some theoretical analysis, different configurations of chamber, flow inlet ducting, and transition chamber, with the purpose of achieving a more efficient flow distribution system within the constraints of available pressure differential and blood flow rate, and the requirements of a high ratio of membrane surface to blood volume for dialysis.
- (g) A new theoretical analysis for dialysis of blood flow through a circular tube has been made. A new flow meter designed for pulsatile blood flow measurement has been calibrated for steady flow, and is being calibrated for unsteady flow. Components for the experimental dialysis unit are being designed.

(6579)

FLOW SEPARATION IN PROSTHETIC HEART VALVES.

- (c) Dr. Zeev Rotem, Dr. V. J. Modi.
- (d) M. A. Sc. thesis.
- (e) It is of great practical importance to obtain detailed understanding of flow phenomena through prosthetic valves. These valves will sometimes fail after several years of satisfactory operation in vitro, and there is reason to believe that at least some of the failures may be explained by inadequate hydrodynamic design. The project involves in its preliminary stages the testing of enlarged models of valves at present commonly used, under conditions of both steady and pulsating flows.
- (g) The literature survey has been completed. The test model of the valve is being instrumented for unsteady pressure study.

(6580)

QUALITATIVE STUDY OF SEPARATED FLOW BEHIND BLUFF BODIES.

- (c) Dr. Zeev Rotem, Dr. V. J. Modi.
- (e) It is intended to study, visually, the wake geometry behind several stationary bluff bodies using a glycerol solution tunnel and Schlieren apparatus.
- (g) The glycerol solution tunnel as well as the Schlieren apparatus have been constructed. The calibration of the tunnel is in progress. Several circular cylindrical models have been

constructed to study the wall effects on the Strouhal number and wake geometry. The model of a prosthetic heart valve has been designed and is under construction.

(6897)

EFFECT OF WALL CONFINEMENT ON THE UNSTEADY AERODYNAMICS OF BLUFF BODIES.

- (c) Dr. V. J. Modi.
- (d) M.A.Sc. thesis.
- (e) To study the effect of wind tunnel walls on mean and fluctuating forces, Strouhal number and wake geometry associated with bluff bodies.
- (g) Measurement of unsteady forces and Strouhal number associated with circular cylinders, with blockage ratio ranging from 0.05 to 0.6, has been completed. The corresponding study of wake geometry and unsteady pressure decay is in progress. The tests are planned for vortex excited condition of the models.

(6898)

EFFECT OF FREE STREAM TURBULENCE ON UNSTEADY AERODYNAMICS OF BLUFF BODIES.

- (c) Dr. V. J. Modi and Dr. V. Ramjee.
- (e) To study, experimentally, the fluctuating forces and wake geometry associated with several bluff bodies when exposed to fluid stream with controlled turbulence level.
- (g) An open circuit wind tunnel with a test section of $1-1/2' \times 1-1/2' \times 8'$ and maximum velocity of 100 ft/sec is under construction. Tests are planned over the turbulence level of 0.05% - 5%.

(6899)

FLOW BEHIND BLUFF BODIES AT LOW REYNOLDS NUMBER.

- (c) Dr. V. J. Modi.
- (d) Senior long-term project.
- (e) To study, both experimentally and analytically, closed streamline flow behind elliptic cylinders as a function of eccentricity and angle of attack.
- (g) A water tunnel with the test section of $24" \times 6"$ has been designed and is under construction. Modification of the existing flume/tow tank facility is under way to make it suitable for the project. Several flow visualization techniques are being studied.

(6900)

RESPONSE OF NEUTRALLY BUOYANT INFLATABLE STRUCTURE TO SURFACE WAVE EXCITATION.

- (c) Dr. V. J. Modi.
- (d) Senior long-term project.
- (e) To study dynamical behaviour of the neutrally buoyant inflatable cantilever beams under the forcing function imposed by the surface waves.
- (g) Modification of the existing water tank facility to adapt it to the present requirement is in progress. Several models, representing systematic variation in diameter and length, have been constructed from Mylar/Polyethylene sandwich material. Measurement of influence coefficients is in progress. Instrumentation for measurement of model shape is under study.

(6901)

THEORY OF ROTATING FLUIDS.

- (b) N. R. C. Canada.
- (c) Dr. Zeev Rotem.
- (e) Investigation of a new type of instability of Ekman layers discovered recently.
- (g) The experimental project is well underway; analysis has started.

(6902)

DEVELOPMENT OF THE KANTROWITZ TEMPORARY CARDIAC-

ASSIST PUMP.

- (b) N. R. C. Canada.
- (c) Dr. Zeev Rotem, Dr. C. E. Rotem, Dr. M. Walters.
- (d) Development.

(6903)

HYDROELASTIC GALLOPING OF BLUFF CYLINDERS.

- (b) N. R. C. Canada.
- (c) Dr. G. V. Parkinson, Dr. T. V. S. tosham.
- (e) A quasi-steady theory is used to predict the galloping of an elastically mounted bluff cylinder; for a square cross-section in air flow, predictions and experimental results are in close agreement. In water flow the theory predicts "asynchronous quenching" of oscillations; experimental investigations of this phenomenon are underway in a low turbulence water tunnel for various cross-sections of bluff cylinders.

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THE UNIVERSITY OF CALGARY, Department of Mechanical Engineering, Calgary 44, Alberta, CANADA. D. H. Norrie, Department Head.

(7319)

NUMERICAL SOLUTION OF FLOW FIELDS.

- (b) National Research Council and Defence Research Board Grants.
- (d) Theoretical; basic research.
- (e) To develop finite element methods for the solution of flow fields, with associated general purpose computer programs, suitable for irregular and multiple boundaries with simple or mixed boundary conditions. The two-dimensional potential flow solution has been obtained. Navier-Stokes, visco-plastic, and compressible flows are under investigation. Further variational and non-variational approaches are envisaged.
- (g) For two-dimensional potential flow good agreement with known solutions has been obtained.
- (h) "The Application of the Finite Element Technique to Potential Flow Problems: Part I." G. de Vries and D. H. Norrie, Rep. No. 7, Dept. of Mech. Engrg., Univ. of Calgary, May 1969.
- "The Application of the Finite Element Technique to Potential Flow Problems: Part II." G. de Vries and D. H. Norrie, Rep. No. 8, Dept. of Mech. Engrg., Univ. of Calgary, July 1969.

(7320)

PRESSURE FLUCTUATIONS OF AXIAL FLOW MACHINES.

- (b) National Research Council and Defence Research Board Grants.
- (d) Theoretical and experimental; basic and applied research.
- (e) The research objective is to determine the unsteady flow field within an axial-flow machine, analytically and experimentally. The analytic solution for the unsteady field is based upon the Biot-Savart superimposition of unsteady fields using the vortex model put forward by Ordway. The solution for the higher harmonics which was partly presented in this reference, using a matrix inversion approach, has been completed. Original alternative solutions based on a Gauss-Legendre quadrature and on Chebyshev functions have been developed, which reduce greatly the calculation necessary. The numerical calculation computer programmes are being developed. For the numerical integrations, various methods were tried, of which the Flinn fifth-order polynomial technique was found to be the most suitable. When the higher-harmonic analytic solution has been completed, this will be applied to a previously

designed ducted impeller system. The theoretical calculations will be compared with experimental pressure data already obtained.

- (g) Calculation of Legendre fluctuations of half-order, and various derived functions, are almost complete. Results of pressure fluctuations are anticipated in late 1970.
- (h) "The Fluctuating Pressure Field of a Ducted Propeller." D. H. Norrie and M. R. Hale, Symposium on Pumping Machinery for Marine Propulsion, ASME Fluids Engrg. Conf., Philadelphia, Penna., May 1968.

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ECOLE POLYTECHNIQUE, Hydraulics Division, 2500 Marie-Guyard Avenue, Montreal 250, P.Q., CANADA. Professor Raymond Boucher, Director, Hydrodynamics Laboratory.

(4043)

STUDY OF THE RELIABILITY AND OPERATION OF BACK-WATER VALVES ON PLUMBING SYSTEMS AGAINST FLOODING BY PUBLIC SEWERS.

- (b) City of Montreal, Permits and Inspections Dept.
- (d) Experimental; applied research.
- (e) A full-scale three-story plumbing system has been erected in the Hydrodynamics Laboratory of Ecole Polytechnique. The diameter of the pluvial column and of the drain is 4 inches; experiments were conducted with soil stacks of 3 and 4 inches in diameter. The drain has many sections of pyrex glass to permit observations at critical points. A system of valves and of cross-connections on the vents lends to various combinations of tests. The back-water valves have a transparent lucite cover to enable visual observations. As air entrainment has a great importance on the venting capacity, the rate of air entrained in the vertical columns is measured at the inlet by means of a hot-wire air-meter. Various flooding conditions of the public sewers are simulated by a tank in which the water level can be controlled by gate valves. This research is aimed at determining whether back-water valves can offer home dwellers a reliable protection against flooding due to any overload of combined sewers.
- (f) Completed.
- (h) Interim and final reports submitted to sponsor under the title "Etude expérimentale des soupapes de sûreté contre les surcharges d'égout." First Interim Report by André Leclerc, Roger Labonté and Raymond Boucher, December 1963; Second Interim Report by André Leclerc, Roger Labonté, Gilles-M. Girard, and Raymond Boucher, August 1968; Third Interim Report by Gilles-M. Girard, and Raymond Boucher, March 1969; Final Report by Gilles-M. Girard and Raymond Boucher, June 1969.

(5947)

HYDRAULIC MODEL STUDY OF HEAD LOSSES THROUGH VARIOUS RESTRICTED ORIFICES FOR THE SURGE TANKS OF MANICOUAGAN 5 HYDROELECTRIC PROJECT.

- (b) Quebec Hydro-Electric Commission.
- (d) Experimental; applied research; M. S. thesis.
- (e) A first model has been built to a scale 1:107.3. Head loss coefficients of various orifice shapes have been studied for the two flow directions under steady flow conditions. To obtain a given loss coefficient ratio for the two flow directions, a final form of the orifice to be installed in the surge tanks has been determined. A second model has been built to a scale of 1:72. No appreciable scale effect has been observed.
- (f) Completed.
- (h) "Etude sur modèle réduit de différents étranglements pour les chambres d'équilibre de l'usine

Manicouagan 5," by Alexandre Godin and Raymond Boucher, juin 1966.

"Etude sur modèles réduits de différentes formes d'étranglement pour une chambre d'équilibre," by Alexandre Godin, M. S. thesis, août 1966.
"Etude sur modèle réduit de différents étranglements pour les chambres d'équilibre de l'usine Manicouagan 5." Supplément No. 1, Laboratoire d'Hydrodynamique, Ecole Polytechnique, mars 1967.

(6822)

SYSTEMATIC MODEL STUDY OF HEAD LOSSES THROUGH RESTRICTED ORIFICES FOR SURGE TANKS.

- (b) National Research Council.
- (c) A. Godin, Assoc. Prof., Hydrodynamics Laboratory.
- (d) Experimental; applied research.
- (e) The purpose of this research is to complete the model study commenced under project (5947). A model built to a scale 1:72 has been used to verify effects of diameter and shape on head-loss coefficients of restricted orifices.
- (f) Completed.
- (h) "Etude fondamentale sur modèles réduits d'étranglements pour chambres d'équilibre." Deuxième rapport soumis au Conseil National de Recherches du Canada. Alexandre Godin, février 1968.

(6823)

TWO-DIMENSIONAL JET IN A STREAMING FLOW.

- (b) National Research Council.
- (c) Luc Robillard, Asst. Prof., Hydraulics Division.
- (d) Experimental and theoretical investigation.
- (e) Experiments have been performed concerning the jet oscillation and vortex shedding that occur when particular experimental conditions are fulfilled. Other experiments are planned to study the reattachment of the jet nappe to the injection device.
- (g) Experimental results indicate that the vortex shedding mechanism is controlled mainly by the interaction of the jet nappe and the uniform flow at high injection velocities.
- (h) "Oscillations périodiques d'un jet bidimensionnel plan et formation de tourbillons alternés." Luc Robillard, Internal Report No. A-4197.

(6904)

STUDY OF AN INTAKE FOR PASSING LOGS AT DAMS.

- (b) Quebec Hydro-Electric Commission.
- (c) Prof. André Leclerc, Assoc. Dir., Hydrodynamics Laboratory.
- (d) Experimental for design and field investigation for prototype verification.
- (e) Study conducted to design the best geometry of an intake that will pass the largest quantity of logs of 4, 8, 12 and 16 feet in length with the minimum amount of water and no danger of jamming.
- (f) Completed.
- (g) An intake has been designed and tested on a 1:16 scale model. Two prototypes installed since the completion of the laboratory study have been investigated during the summer of 1969 and verified to agree very well with the results obtained on the scale model.
- (h) "Le passage des billots aux barrages - Etude sur modèle réduit partie I: Etude des tabliers d'entrée; partie II: Etude des échelles mécaniques." Joint report prepared by the Quebec Hydro-Electric Commission and Ecole Polytechnique, Jan. 1967.
"Le passage des billots aux barrages - Mesures sur prototype pour vérifier le comportement du tablier d'entrée." Mars 1970, La Commission Hydroélectrique du Québec.

(6905)

BEHAVIOUR OF LOGS FLOATING IN PRISMATIC CHANNELS.

- (c) Prof. André Leclerc, Assoc. Director, Hydrodynamics Laboratory.
- (d) Experimental and theoretical; for Master's thesis.
- (e) To determine the velocity of logs relative to water under conditions of steady uniform flow.
- (g) The influence of various factors on the relative velocity of the logs has been studied: length and diameter, slope of flume, rate of flow. Two different flow sections have been investigated, rectangular and semi-parabolic. Other sections are considered.
- (h) "Etude sur modèle réduit du comportement des billots en canal prismatique." Pierre Dumas, M.S. thesis, Sept. 1967. A second report is in preparation.

(6906)

MODEL STUDY OF A LOG CHUTE FOR THE BRYSON HYDRO-ELECTRIC DEVELOPMENT.

- (b) Quebec Hydro-Electric Commission.
- (c) Prof. Raymond Boucher, Director, or Prof. André Leclerc, Assoc. Director, Hydrodynamics Lab.
- (d) Experimental; for design.
- (e) Reconstruction of a new log chute became necessary due to operating difficulties and insufficient capacity of the existing one.
- (g) A model has been built to a scale of 1:16 in order to study the transition between the intake and the flume itself, and also the amount of excavation required in the river in the vicinity of the intake. The minimum slope of the flume has been determined for a safe operation without jamming. Another model will be built to study the behaviour of logs as they plunge into shallow water after leaving the upturned bucket at the end of the flume.
- (h) Report in preparation.

(6907)

STUDY OF THE BEHAVIOUR OF LOGS IN RADIAL UPTURNED BUCKETS WITH RECTANGULAR FLOW SECTIONS.

- (c) Prof. André Leclerc, Assoc. Director, Hydrodynamics Laboratory.
- (d) Theoretical and experimental for design; for Master's thesis.
- (e) To determine the velocity of logs relative to water and the change of this relative velocity throughout the bucket. The purpose is to predict the outlet velocity of logs from buckets having varying radii and lengths. The model is built to a scale of 1:16.
- (g) A theoretical expression has been derived for the water velocity and the log velocity, using the energy principle. Experiments show good agreement with the theoretical investigation.
- (h) "Etude à échelle réduite du passage des billots dans des canaux rectangulaires avec courbure dans le plan vertical." André Leclerc et Norman McNeil, 1967.
"Etude théorique de la vitesse des billots dans des canaux rectangulaires à courbure verticale." André Leclerc et Pierre Dumas, Oct. 1969.

(6908)

MATHEMATICAL MODEL TO COMPUTE THE RUNOFF HYDROGRAPH OF A WATERSHED RESULTING FROM SPECIFIC RAIN PERIODS.

- (c) Prof. André Leclerc, Assoc. Director, Hydrodynamics Laboratory.
- (d) Theoretical; for Master's thesis.
- (e) Hyetographs are established for every Thiessen polygon on the basin. Areas of the basin equidistant from the outlet are considered as isochrone areas. The total runoff during one hour

is computed as the summation of elementary volumes flowing from each equidistant area, taking into account the time required to reach the outlet. A routing function as suggested by Larrieu in France, has been tested to account for the effect of storage on the watershed.

- (g) A programme in Fortran language is operating properly. The model has been tested on six storm periods for which runoff hydrographs had been obtained on two water sheds. Agreement between observed and measured hydrographs varies widely from period to period, suggesting that the assumptions on which the mathematical model is based are oversimplified.
- (h) M.S. thesis under preparation by P. A. Bolduc.

(6909)

WATERHAMMER ANALYSIS IN PLASTIC PIPES.

- (b) National Research Council of Canada.
- (c) Assoc. Professor Alexandre Godin.
- (d) Experimental; basic research.
- (e) Determination of maximum rise and minimum drop in head in a plastic pipe by sudden or progressive closure of a valve. Tests will be performed on different types and sizes of plastic pipes. Evaluation of the pressure wave celerity and determination of the pipe deformation.
- (f) Apparatus completed.
- (g) Preliminary recordings taken for a 2-in. diameter PVC pipe.

(6910)

TIDAL MOTION IN THE ST. LAWRENCE ESTUARY BETWEEN ANTICOSTI ISLAND AND LAKE ST. PETER.

- (b) National Research Council of Canada.
- (c) Dr. H. Werner Partenscky, Prof. of Hydraulics, Hydrodynamics Laboratory.
- (d) Theoretical study based on field measurements; M.Sc. thesis.
- (e) Investigation of the tidal characteristics of the St. Lawrence Estuary by means of a linearized mathematical model. Assumption of a negative reflection of the incoming tidal wave at Lake St. Peter. Derivation of basic equations. Empirical determination of geometric and roughness effects on tidal amplitudes and velocities. Numerical integration of equation of motion to determine tidal discharge. Comparison of theoretical solution with field data.
- (f) Completed.
- (g) Theoretical results showed good agreement with prototype measurements.
- (h) "Damped Co-Oscillating Tide With Negative Reflection at the End of an Estuary." H. W. Partenscky and J. C. Warmoes, Proc., XIIIth Congr., Int. Assoc. Hydraulic Res., Paper C-39, Vol. 3, Sept. 1969, Kyoto, Japan.
"Etude des marées dans l'estuaire du Saint-Laurent entre l'île Anticosti et Lac St-Pierre." H. W. Partenscky and J. C. Warmoes. Report submitted to National Research Council of Canada, May 1969, Ottawa.

(6911)

STUDY ON THE INSTABILITY OF THIN WATER CURTAINS AND OSCILLATIONS OF FLAP GATES.

- (b) National Research Council of Canada.
- (c) Dr. H. W. Partenscky, Prof. of Hydraulics, Hydrodynamics Laboratory.
- (d) Experimental and theoretical; fundamental study; M.Sc. thesis.
- (e) The excitation of thin water curtains to vibrate has been studied under different operating conditions. Critical conditions for the instability of the nappe have been determined by means of systematic tests.

- The effect of elastically supported flap gates on the excitation of water bands has been studied. An attempt is made to describe the resulting coupled oscillations theoretically.
- (f) Tests completed; report in final stage.
 - (g) Operation criteria for flap gates have been established to avoid vibration phenomena.
 - (h) "Etudes des vibrations de lames déversantes." H. W. Partensky and I Sar Khloeng. Report submitted to the National Research Council of Canada, Juillet 1969, Ottawa.
- (6912)
SIMULATION OF OCEAN WAVE SPECTRA IN A LABORATORY WAVE FLUME.
- (b) National Research Council of Canada.
 - (c) Dr. H. W. Partensky, Prof. of Hydraulics, Hydro-dynamics Laboratory.
 - (d) Theoretical and experimental study; D.Sc. thesis.
 - (e) The purpose of the study is to establish operating criteria for a new wave maker installed in the towing tank of Ecole Polytechnique, Montreal. The system permits selection of an ocean wave spectrum with up to 20 frequency bands. The simulation of given wave spectra in the canal of limited length (180 ft.) by means of the existing installation is the final aim of the study.
 - (g) Final report to be expected December 1970.
- (6913)
LAMINAR BOUNDARY LAYER ALONG A MOVING FLAT BELT.
- (b) Quebec Government.
 - (c) Luc Robillard, Asst. Prof., Hydraulics Division.
 - (d) Theoretical investigation.
 - (e) This research project was undertaken for a better understanding of the establishment of velocity profiles in turbulent Couette-Poiseuille flow experiments.
 - (f) Completed.
 - (g) A generalized Blasius series has been established. The method of steepest descent has been used to evaluate the constant of integration from the boundary condition at infinity.
 - (h) "Couche limite laminaire le long d'une courroie mobile." Luc Robillard, CANCAM Proc., Waterloo, May 1969.
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- UNIVERSITY OF GUELPH, School of Engineering, Hydrology Section, Guelph, Ontario, CANADA. Dr. W. T. Dickinson, Assistant Professor.
- (2740)
MAIN TILE SIZE DRAINS FOR COMPOSITE DRAINAGE.
- (c) Professor R. W. Irwin.
 - (d) Field investigation; applied research.
 - (e) Measurements of tile discharge from several field laterals have been made during the April-October period over a ten year period. During the past five years additional lines placed at the mid-spacing have also been measured to determine the effect of closer spacing.
 - (f) Discontinued.
 - (g) "Computer Simulation of Tile Systems," N. A. Bird, J. A. McCorquodale. Presented to the annual meeting ASAE, Chicago, Dec. 1969.
- (6604)
HYDROLOGY OF BLUE SPRINGS BASIN.
- (c) Professor H. R. Whiteley.
 - (d) Field investigation; basic research.
 - (e) Comprehensive monitoring of several components of the hydrologic system on this 20-sq. mile basin will provide the basis for development of a mathematical model from which synthetic stream flow data may be generated for basins formed from glacial moraine deposits.
 - (g) Two years observations indicate large contributions of groundwater flow and considerable variability in source area contribution.
 - (h) "Watershed Areas Contributing to Runoff," W. T. Dickinson and H. Whiteley. Submitted to the Int. Symp. on the Results of Research on Representative and Experimental Basins, Wellington, New Zealand, Dec. 1970.
- (7321)
CHARACTERISTICS OF HYDROGRAPH RECESSIONS.
- (b) National Research Council.
 - (d) Theoretical investigation; basic research; Master's degree.
 - (e) The objective of this project has been to characterize the seasonal and spatial variability of stream hydrograph recessions in Southern Ontario. This portion of the runoff hydrograph yields considerable information regarding the response nature of a watershed.
 - (g) The frequency distribution of daily recession rates and the variability of this distribution seasonally and spatially, has been found to be useful in characterizing response. It is anticipated that this approach might lead to criteria for selecting watershed response models.
- (7322)
EXTREME STREAMFLOW PARAMETERS IN ONTARIO.
- (b) National Research Council.
 - (c) Dr. W. T. Dickinson.
 - (d) Analytical investigation; basic research; Master's degree.
 - (e) Characteristics of extremely high streamflows in Ontario appear to vary regionally and with watershed parameters within regions. The purpose of this project is to normalize extreme value functions for regions of the province, utilizing watershed parameters of area, stream slope, and storage.
 - (g) It has been observed that the parameters of an extreme value distribution applied to high streamflows in Ontario assume regional characteristics. Further, within these regions, the variability of the parameters can be associated with changes in watershed characteristics.
- (7323)
RUNOFF FROM FLAT LAND.
- (c) Professor R. W. Irwin.
 - (d) Field investigation; applied research.
 - (e) Measurements of precipitation and stream discharge from a three-thousand acre flat, heavy clay watershed have been made.
 - (g) No analysis of data has been made.
- (7324)
WATER FLOW UNDER ICE.
- (c) Professor Gee Tsang.
 - (d) Theoretical, experimental and field-observational study. The project may be classified between basic research and applied research.
 - (e) Field measurements will be obtained to provide information of water flow under ice and scouring at river bed. Laboratory simulation will be made to isolate different affecting parameters. Theories will be developed to explain and predict the variation of resistance in a natural river, the increase in scouring at the river bed during surface icing, and the suppressing effect of ice particles on turbulence.
 - (g) Field measurements have shown considerable bed

scouring due to surface icing. The frazil ice-water mixture has an effect of suppressing turbulence mixing.

(7325)

AN ABLATION MODEL FOR SHALLOW SNOWPACKS.

- (c) Prof. H. D. Ayers.
- (d) Field investigation; basic research; Master's degree.
- (e) A relatively shallow snowpack exists in Southern Ontario for several months of the year and contributes substantial moisture to the hydrologic regime of the area. The purpose of this project has been to develop an analytical model for the monitoring of changes in a shallow snowpack and the apportioning of water losses to evaporation, sublimation, and drainage.
- (f) Completed.
- (g) The energy and mass balance approach to the problem resulted in a most satisfactory model. A comparison of model and field results for two winter seasons is encouraging.

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H. G. ACRES LIMITED, Consulting Engineers, 1259 Dorchester Road, Niagara Falls, CANADA. W. L. Gibson, Vice President.

(7379)

ICE COVER MODEL STUDIES FOR KETTLE RAPIDS HYDRO-ELECTRIC PROJECT ON THE NELSON RIVER.

- (b) Manitoba Hydro, Winnipeg, Manitoba, Canada.
- (d) Experimental; for operational procedures.
- (e) An essential requirement for winter construction and subsequent winter operation of Kettle Generating Station is the formation of a stable ice cover. A model of the Nelson River to a scale of 1:400 horizontally and 1:100 vertically was made of the five miles upstream of the site. Small pieces of polyethylene specially treated so as to be cohesive were introduced to form an "ice cover." Actual site flow conditions were simulated from day-to-day information and the "ice cover" formations produced on the model were found to duplicate the site with an accuracy that warranted the acceptance of further test results with complete confidence.
- (f) Completed.
- (g) The forebay elevation determined by the model tests as the minimum for the following winter construction period did, in fact, produce a very satisfactory ice cover.
- (h) Report prepared and submitted to client.

(7380)

SCOUR STUDIES FOR GRAND RAPIDS HYDRO-ELECTRIC STATION SPILLWAY.

- (b) Manitoba Hydro, Winnipeg, Manitoba, Canada.
- (d) Experimental; design.
- (e) Following completion of the spillway of the Grand Rapids Hydro-Electric development, a series of construction delays occurred which necessitated the passage of substantial quantities of water through the spillway. Consequently, the scour hole anticipated downstream from the flip bucket developed to its design depth over a much shorter period of time than originally envisaged. In order to eliminate the possibility of undesirable deeper scour, erodible bed model studies were undertaken. These were to modify the design to redirect energy dissipation of the flow away from the structure. A comprehensive 1:72 scale model of the approach, spillway, and downstream channel, and a sectional

1:40 scale model of the spillway section and downstream riverbed were used to simulate the erosion pattern and mechanism.

- (f) Design completed; contract awarded for construction.
- (g) Remedial construction, recommended as a result of the model tests, consisted of removal of the spillway bucket and addition of a sloping apron with a steep solid endsill and flared wingwalls. Revisions to gate operating procedures recommended.
- (h) Report prepared and submitted to client.

(7381)

TAPERED CHUTE SPILLWAY FOR THE ALTO ANCHICAYA HYDRO-ELECTRIC POWER PROJECT.

- (b) Corporacion Autonoma Regional Del Cauca - CVC Cali, Colombia.
- (d) Experimental; design.
- (e) Topography at the damsite for the high head hydro power development on the Rio Anchicaya required a steeply sloping chute spillway with a flip bucket. Construction economies suggested that a tapered chute would be desirable. A 1:65 model of the approach topography, structure and downstream channel with an erodible bed was constructed. A study was undertaken to investigate optimum chute configuration, wave patterns, chute sidewall height, flip bucket jet performance and erosion of the downstream riverbed.
- (f) Design completed; tenders called for construction.
- (g) Tests resulted in the adoption of a structure design giving fully satisfactory performance at all design discharge rates, and having relatively flexible gate operation requirements. Considerable savings over a conventional straight chute configuration are expected.
- (h) Report prepared and submitted to client.

(7382)

MODEL TEST OF INVERTED SYPHON UNDER WELAND CANAL.

- (b) St. Lawrence Seaway Authority, Montreal.
- (d) Experimental; design.
- (e) For the relocation of part of the Seaway Canal near Welland, Ontario, the Welland River has to be conducted under the canal by means of a 600-foot long inverted siphon. To investigate the loss in head through the siphon during extreme floods, the hydraulic performance of the proposed siphon was checked by means of a hydraulic model. Constructed entirely of plexiglas and to a scale of 1:30, two of the four conduits were modeled along with some 180 feet of the approach channel and a similar length of exit channel. Since the geometry at each end of the siphon was different, the model was arranged so that the flow could be in either direction. This enabled the relative merits of each end configuration to be assessed both as an inlet and an outlet in the same model. Detailed hydraulic loss measurements were made. Since model flows were scaled according to Froude criteria for similitude, the effect of the resulting discrepancy between the model and prototype Reynolds numbers was also investigated by increasing the flow through the model by a factor of approximately three. The transparent material of which the model was constructed enabled visual examinations and photographs to be taken of the siphon's ability to handle ice flows and water-logged debris.
- (f) Completed.
- (g) On the basis of the model tests, it was concluded that the total head loss for the prototype siphon will be not more than four inches at the design flood flow of 9,000 cfs, well within the design objective of 12 inches. Head losses through the outlet transition were slightly less than those through the inlet. It was shown that ice will

not in general pass through the syphon until the flow exceeds 4,800 cfs, and that at 6,800 cfs ice sheets 15 feet square by 9 inches thick will pass through. Floating debris small enough to be transported into the syphon will pass through. Heavily waterlogged debris will not be transported into the syphon because of the low velocities in the approach channel.

- (h) Report prepared and submitted to the client.

(7383)

TAILRACE SURGE CHAMBER FOR CHURCHILL FALLS POWER PROJECT.

- (b) Acres Canadian Bechtel of Churchill Falls, Montreal, Quebec.
- (d) Experimental; design.
- (e) The tailrace tunnels leading out of the underground powerhouse at the Churchill Falls Project in Labrador are each 5,500 feet long. Pressure surges from these tunnels following a full load rejection will be accommodated in a large underground surge chamber, the dimensions of which were determined by analytical methods. In order to evaluate the form losses and flow characteristics during steady state operation, a 1:50 scale model was built comprising one tunnel and one-half of the surge chamber. Tests were performed principally to determine the effect of varying the surge chamber cross-sectional shape, the submergence of the tailrace tunnel inlet and its lateral location, the shape of the tunnel inlet, and the detailed geometry of the surge chamber to minimize turbulence, air entrainment and vortices.

- (f) Completed.
- (g) Improved flow conditions were observed in a key-hole-shaped chamber. The form losses for the tunnel inlet decreased as the submergence was increased but were further reduced when the tunnel inlet was positioned opposite a draft tube exit. As a result of the tests, a system of beams was added between the draft tube gate guides to prevent vortex formation and guide vanes on the downstream wall to improve the flow.
- (h) Report prepared and submitted to client.

(7384)

CHUTE SPILLWAY FOR LOWER NOTCH HYDRO-ELECTRIC STATION.

- (b) Hydro-Electric Power Commission of Ontario, Toronto, Canada.
- (d) Experimental; design.
- (e) A flip-bucket spillway was selected for the Lower Notch Hydro-Electric development, rather than the more conventional stilling basin arrangement. The spillway is located at the end of an excavated channel which also serves the powerhouse intakes. An interior confining wall is provided in the chute to ensure adequate throw of the flip-bucket jet at small discharges. A hydraulic model study, utilizing a comprehensive 1:64 scale representation of the spillway and adjacent works, was undertaken to consolidate the design calculations.
- (f) Design completed; construction in progress.
- (g) Model scour tests using a loose, crushed rock erodible bed demonstrated that the spillway design gives completely satisfactory performance at all design discharges. Model tests also confirmed, with minor modifications, the hydraulic design of the roadway, piers, chute walls and flip-bucket. Based on observations in the model, the construction of a groin between the jet landing area and the tailrace was recommended to prevent siltation of the tailrace channel by spillway discharges.
- (h) Report prepared and submitted to owner.

(7385)

NAN RIVER HYDRAULIC MODEL.

- (b) Electricity Generating Authority of Thailand (EGAT).
- (d) Experimental; for design.
- (e) A hydraulic model to investigate the effects on irrigation and navigation due to the intermittent operation of the proposed Sirikit Power Development in 300 Km reach of the Nan River below the development. The model, under construction at Bangkok, Thailand, is built to scales of 1:40 vertically and 1:600 horizontally. Provision is made to extend the model to simulate the next 140 Km approximately, of the river to beyond the confluence with the Ping River if required. Automatic programming of the river flows is provided and remote sensing of stage heights enables the resulting hydrographs to be plotted by an oscillograph located in the console in the control building. The test program will also include an investigation of the possibility of reducing the effects of intermittent operations by the construction of a regulating after-bay immediately downstream from the powerhouse under construction.
- (f) Under construction.

(7386)

MODEL STUDY OF THE COTE STE. CATHERINE LOCK REGULATING CHANNEL.

- (b) The St. Lawrence Seaway Authority, Montreal.
- (d) Experimental; design.
- (e) A proposed change in mode of operation of the Cote Ste. Catherine Lock regulating channel calls for the flow rate to be increased for limited periods by a factor of between three and four. To study the effects of the increased flow and provide design information, a 1:40 scale model of the regulating channel was built. This comprised the control structure at the upstream end, a water level regulating weir, the entrance of a small river near the midpoint and a bridge at the downstream end.
- (f) Completed.
- (g) The model showed that scouring velocities below the control structure could be reduced to acceptable levels by symmetrical operation of the six gates and that baffle blocks constructed in the basin below the regulating weir would effectively maintain the hydraulic jump within the basin for all flows up to and exceeding the proposed maximum.
- (h) Report prepared and submitted to client; also motion picture report.

(7387)

WHITEFISH CONTROL STRUCTURE FOR CHURCHILL FALLS HYDRO-ELECTRIC POWER PROJECT.

- (b) Acres Canadian Bechtel of Churchill Falls, Montreal 215, Quebec.
- (d) Experimental; design.
- (e) The Whitefish Falls Control Structure is required to pass the power flow of 60,000 cfs with only two of the three gates in operation and must be capable of passing a maximum flood of 103,000 cfs through all three. A model, built to a scale of 1:60 of the structure and the surrounding topography for a distance of 200 feet upstream and downstream was used to complete the design.
- (f) Completed.
- (g) Model tests indicated certain design economies could be made and that a dentated deflector-sill should be introduced to reduce bottom velocities downstream from the structure.
- (h) Report prepared and submitted to the client.

(7388)

MODEL STUDY OF THE JUNCTION OF THE SEAWAY CANAL AND THE REGULATING CHANNEL BELOW THE COTE STE. CATHERINE LOCK.

(b) The St. Lawrence Seaway Authority, Montreal.

(d) Experimental; for design.

(e) To meet operating requirements of the St. Lawrence Seaway Authority, the rate of flow from the regulating channel past the Cote Ste. Catherine Lock is to be increased by a factor between three and four from the present maximum of 3,000 cfs. Although the water is readily available, the configuration of the junction with the navigation channel is such that the turbulence due to any higher flow is detrimental to navigation. A model to a scale of 1:60 was used to study the turbulence caused by various rates of inflow and their effects on navigation. Dynamometers were used to record the forces on a model ship located in the area. A radio controlled ship was used to demonstrate the effect of changes made to the configuration of the junction on ships entering and leaving the lock, and when passing other ships while in the vicinity of the inflow.

(f) Completed.

(g) Construction of guide walls at the outlet of the regulating channel and some widening immediately downstream of the inlet were shown to be effective in diverting the turbulence away from the navigation channel.

(h) Report prepared and submitted to client.

(7389)

LOBSTICK CONTROL STRUCTURE FOR CHURCHILL FALLS HYDRO-ELECTRIC POWER PROJECT.

(b) Acres Canadian Bechtel of Churchill Falls, Montreal 215, Quebec.

(d) Experimental; for design.

(e) The Lobstick Control Structure is the sole outlet for the main Churchill Falls reservoir and has a flood capacity of 230,000 cfs. It must also operate continuously, discharging up to 66,000 cfs for power generation. Once in operation, the stilling basin will be permanently submerged at all flows.

A model of the structure and the surrounding topography to a distance of 2,000 feet, both upstream and downstream, was built to a scale of 1:100. Tests were made to verify the stilling basin geometry and the flow conditions in the channel upstream and downstream of the structure. The flow depth and velocity resulting from the diversion closure were examined and the discharge rating curves for the structure were established.

(f) Completed.

(g) On the basis of the model tests, it was shown that the hydraulic jump will stay within the stilling basin at maximum flow even if the tail-water level downstream from the structure is reduced by as much as five feet below normal; the design was modified, however, to minimize any chance of erosion of the permanently submerged concrete basin.

(h) Report prepared and submitted to client.

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THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO,
Hydraulic Model Laboratory, Hydraulic Studies Department,
620 University Avenue, Toronto 2, Ontario,
CANADA. Mr. J. B. Bryce, Hydraulic Studies Engineer.

(4026)

NIAGARA RIVER MODEL.

(d) Experimental; for design and operation.

- (e) An existing 1:250 x 1:50 scale model reproducing five miles of the Niagara River from Buckhorn Island to below the Cataracts is being used to determine the operational characteristics of the Niagara River Control Structure under developed conditions. This model was previously used to investigate the remedial works necessary for the preservation and enhancement of Niagara Falls and for the location of the intakes and necessary river improvements of both Ontario Hydro and the Power Authority of the State of New York. To fully realize the terms of the 1950 Niagara Treaty, additional remedial works have been designed. These include a five-gate extension to the existing 13-gate control structure as well as a system containing an upstream accelerating wall, a downstream training wall and overflow weir for the safe passage of ice past the various intakes along the Canadian shore of the river above the Falls. The sequence of construction of these works and the conditions during their construction were determined in the model. Rating of the structure under cofferdammed conditions was obtained. An echo-sounding survey with electronic fixing was made in the field in 1962 and portions of the model recontoured. Certain river improvements were designed and executed to assist in the passage of ice floes.
- (f) Design completed, but model still operational.

(4455)

ARROW LAKES DAM - COLUMBIA RIVER.

(b) British Columbia Hydro and Power Authority.

(d) Experimental; for design and operation.

(e) A 1:80 scale model of the Arrow Lakes and dam and environs was built to determine the detailed location and adequacy of the water passages in a concrete structure and the energy-dissipating works necessary to ensure the protection of an associated earth dam. Numerous tests have been made with a movable bed of fine sand to determine erosion characteristics and navigation velocities upstream and downstream of a lock situated between the concrete structure and the earth dam.

(f) Design completed, but site model still active.

(6938)

LAMBTON GENERATING STATION.

(d) Experimental; for design.

(e) A 1:60 scale model of the intake and discharge channels leading to the St. Clair River was built to locate and design a suitable boom system to exclude ice floes, debris and coal dust from the intake for condenser cooling water to this 2,000 Mw. fossil-fueled plant.

(f) Design completed but model inactive.

(6939)

PICKERING GENERATING STATION.

(d) Experimental; for design.

(e) A 1:36 scale model was built of the entrance from Lake Ontario, screenhouse, forebay and two distinct pump well designs to determine the better overall well design (whether 45° or 90°), as well as the details of shape and grade of the various condenser cooling water passages of this 2,000 Mw. nuclear station.

(f) Design completed, model discontinued.

(6940)

LAKEVIEW GENERATING STATION.

(d) Experimental; for design and operation.

(e) A 1:24 scale model of the intake canal from Lake Ontario was built to locate the recirculating channel outlet for best mixing and supply of warm-

- ed water to the first four units of this fossil-fueled 2,400 Mw. plant. On the discharge side of the condenser cooling water system for units 1 and 2, the design of the inlet structure and ducting to control this recirculating water was determined.
- (f) Design completed but model inactive.

(6941)

NANTICOKE GENERATING STATION.

- (d) Experimental; for design.
- (e) A 1:36 scale model of the condenser cooling water system consisting of the exit from a 21-foot diameter tunnel under Lake Erie to vertical shaft leading to forebay - pumphouses entrances - tempering water channel, pumphouse and exit - discharge structure from 8 units and discharge mixing channel to the lake. The location, shape and grade of all these components were determined in this comprehensive model of the cooling water system of the first half of this 8 unit 4,000 Mw. fossil-fueled steam plant.
- (f) Design completed but model inactive.

(6942)

NANTICOKE GENERATING STATION.

- (d) Experimental; for design and research.
- (e) A 1:12 scale model in plexiglass of the eight-foot square concrete discharge ducts from the first four units of this fossil-fueled steam plant was built to determine any water hammer pressures that might exist in the long ducts (longest 1,300 feet) in the event of pump trip-off that would exceed the design of the duct walls. The number, location, type and size of any air inlet valves in the duct systems will be determined, as well as the behaviour and characteristic of the entrained air.
- (f) Model being constructed.

(6943)

BRUCE GENERATING STATION.

- (d) Experimental; for design.
- (e) A 1:24 scale model was built of a portion of the forebay with two distinct pump well designs. One was a single channel with a 14-foot travelling screen, and the other a double channel with two 10-foot travelling screens. Comparative testing proved the superiority of the double channel and determined the design details of bottom, back and side clearances for the four pumphouses containing three pumps each for a total capacity of 6,000 cfs of condenser cooling water for this 2,000 Mw. nuclear plant.
- (f) Design complete, model inactive.

(6944)

BRUCE GENERATING STATION.

- (d) Experimental; for design.
- (e) A 1:13.7 scale model was built in plexiglass of the large discharge pipe from the cooling water pump entering a manifold or header and then bifurcating into smaller pipes to the inlet to the condenser. The initial design led to large hydraulic and shock losses but redesign reduced these losses considerably to well within the head range of the pumps. Each prototype manifold will have three pipes inlet and six pipes to the condenser.
- (f) Design complete, model inactive.

(6945)

BRUCE GENERATING STATION.

- (d) Experimental; for design.
- (e) A 1:50 scale model was built of the complete condenser cooling water system from the intake in

the bed of Lake Huron, the tunnel, tunnel exit, canal leading to the forebay, four pumphouses, discharge channel beneath power house, recirculating channel, to discharge into the lake. The hydraulic design details and performance of all elements of the system will be determined.

(f) Model being constructed.

(6946)

LENNOX GENERATING STATION.

- (d) Experimental; for design.
- (e) A 1:50 scale model is being constructed of the features of the condenser cooling water system including intake in the bed of Lake Ontario, tunnel, tunnel exit, forebay, discharge structure, recirculating channel, energy dissipators in discharge channel, tempering water pumphouse on dyke and discharge channel for mixing behind the dyke offshore. All elements of the system will be determined in detail and performance assured of this 2,200 Mw. oil-fired thermal station.
- (f) Model being constructed.

LASALLE HYDRAULIC LABORATORY LTD., 0250 St. Patrick Street, LaSalle, P.Q., CANADA. R. Hausser, Vice President.

(6226)

TIDAL POWER PRODUCTION - BAY OF FUNDY.

- (b) Atlantic Tidal Power Programming Board, Halifax, N. S.
- (d) Theoretical (a computer study).
- (e) Development of a computer program for determining optimum power and energy generation for various tidal power developments. The following parameters can be introduced in the program: six way operations of the unit (turbining, pumping or sluicing in both directions) with, of course, real turbine characteristics for all type of operations. Sluiceway capacity - generator rating - backwater effect in the basin - variation of cost of energy with the hour of production (peaking problem) - limit due to levels or gradient of discharges (wave problems), etc. Operation of the program for determining power and energy generation of selected tidal power development sites, optimization of operation and equipment.
- (f) Completed.
- (h) Report submitted.

(6227)

TIDAL PROPAGATION IN THE BAY OF FUNDY.

- (b) Atlantic Tidal Power Programming Board, Halifax, N. S.
- (d) Theoretical - mathematical model.
- (e) Development and adjustment of a mathematical model (using an IBS 360-50) reproducing accurately existing tidal regime in the whole Bay of Fundy. Operation of the model to analyze effect on tidal regime, of building and operating various possible tidal power plants.
- (g) Very satisfactory agreement has been obtained between observed and computed values of tidal elevations, amplitudes and phases.

(6228)

LAKE ST. PETER.

- (b) Department of Transport, Canada.
- (d) Experimental.
- (e) Study of the effect of dyking the Ship Channel in Lake St. Peter between Montreal and Quebec. Study carried out on a model built to scales of 1/75 vertically and 1/600 horizontally.

- (6236)
UPPER AND LOWER BEAUHARNOIS ST. LAWRENCE SEAWAY LOCKS.
(b) The St. Lawrence Seaway Authority, Montreal.
(d) Model investigation.
(e) Hydraulic testing of cross-culverts discharging directly below the upstream mitre gates, so as to produce a positive flow for flushing the ice and providing longitudinal hydraulic assistance to the ships as they leave the lock (scale 1/20).
(f) Completed.
(h) Report submitted to sponsor.
- (6237)
WELLAND LOCKS - MODEL STUDY OF PORTS.
(b) The St. Lawrence Seaway Authority, Montreal.
(d) Theoretical and experimental.
(e) Basic study on the hydraulic performance of various types of ports in view of repair and rehabilitation of lock chamber walls. The model produces a single port connecting a culvert and a lock chamber (at a scale of 1/18) and computations enable the data from the model to be applied to an entire lock.
(f) Completed.
(h) Report submitted to sponsor.
- (6239)
ICE TESTS ON THE ST. LAWRENCE RIVER MODEL.
(b) Department of Transport.
(d) Theoretical and experimental; design.
(e) Ice tests are under way on 1/150 vertically and 1/600 horizontally scale model of the St. Lawrence River in the reach of Laprairie Basin - Lanoraie in order to study the ice conditions and the solution to improve them in regard to flood risks during winter.
- (6914)
VIBRATIONS OF FUEL BUNDLES IN AN ATOMIC REACTOR.
(b) Atomic Energy of Canada Ltd.
(d) Theoretical, model investigation and design.
(e) Studies on a double size scale model of the fuel inlet assembly of the Gentilly Nuclear Power Plant. The model was used for determining the possible causes of vibrations experienced during the removal of the fuel bundles from the reactor. The tests consisted in measuring the velocity and pressure distributions at different points around and inside the bundle. Results of tests were used to define modifications to the design which were later verified on a test loop using prototype fuel bundles.
(f) Completed.
(h) Report submitted to sponsor.
- (6915)
WELLAND CANAL LOCK NO. 7.
(b) The Saint-Lawrence Seaway Authority, Montreal.
(d) Model investigation.
(e) Study of the performance of pneumatic wheel fenders installed in recesses of lock chamber walls. The model reproduced at a scale of 1/48, the complete lock with its emptying and filling system and the approach channels. Two radio-controlled scale model ships were available for the studies. Tests were made to define the performance of the fenders in guiding ships into and out of the lock.
(f) Completed.
(h) Report submitted to sponsor.
- (6916)
TRAINING OF THE SAINT-CHARLES RIVER.
(b) Beaulieu, Piette, Trotter, Vandry and Associates, Consulting Engineers.
- (d) Model investigation.
(e) Studies on a movable bed distorted scale model (1/32 vertical and 1/180 horizontal scales) of the influences of the estuary damming and of the river training on the bed transport regime of the river. Tidal conditions and variable river flow conditions were simulated.
(f) Completed.
(g) Report submitted to the client.
- (6917)
MANICOUAGAN 3 - DIVERSION WORKS.
(b) Hydro-Quebec.
(d) Model investigation.
(e) Study on a 1/100 scale movable bed model of the different phases of construction and utilization of the diversion works. Simulation of ice and timber passage through the tunnels.
(f) Studies continuing to develop later stage works for the diversion.
- (6918)
NORTHUMBERLAND STRAIT CROSSING (BRIDGE SECTION).
(b) Northumberland Consultants Limited, Montreal; Department of Public Works of Canada, Ottawa.
(d) Experimental and theoretical, design.
(e) Wave tank study at scale 1/60 to determine the hydrodynamic forces on bridge piers arising from the joint action of waves and currents. Two types of piers were to be tested: a caisson-supported pier, and a pile-supported pier.
(f) Completed.
(h) Report submitted to sponsor.
- (6919)
NORTHUMBERLAND STRAIT CROSSING (CAUSEWAY SECTION).
(b) Northumberland Consultants Limited, Montreal; Department of Public Works of Canada, Ottawa.
(d) Experimental, design.
(e) Flume tests at scale 1/40 to investigate the stability of the profile at various stages of completion, and to give some idea of the probable extent of damage likely to be inflicted by storms during the period of construction.
(f) Completed.
(g) Report submitted to sponsor.
- (6920)
FOOT BERM STABILITY IN RUBBLE-MOUND BREAKWATERS.
(d) Theoretical and experimental.
(e) Flume tests aimed at investigating the unit weight of stone required in the foot berms of a profile, given the depth of the berm below the surface, the water depth in which the structure is located, and the wave attack conditions.
(f) Completed.
(h) "Essais en canal à houle sur la stabilité des enrochements de butée de pied dans les digues à talus." Richard Boivin, Engrg. J., Engrg. Inst. Canada, Vol. 51, No. 9, September 1968, 36-39.
- (6921)
PATTERN OF WAVE-INDUCED EROSION UNDER CAISSON-TYPE BREAKWATER.
(b) Department of Public Works of Canada, Design Directorate, Ottawa.
(d) Experimental and theoretical, design.
(e) This investigation was undertaken to clarify the mechanism by which extensive foundation damage was caused to a recently installed prototype structure. It was suspected that the problem was caused by erosion of the foundations by wave action, which began at a joint between abutting caissons and extended progressively under the caissons. A laboratory study was undertaken to

- obtain a better insight into the erosion phenomenon, devise the most effective way to prevent this problem in future installations, and assist in the design of an appropriate repair method for the damaged structure.
- (f) Completed.
- (h) Two reports submitted to sponsor.
- "Pattern of Wave-Induced Erosion Under Caisson-Type Breakwater." P. Donnelly and Richard Boivin, 11th Coastal Engrg. Conf., London, 1968, Vol. 1, pp. 599-606.
- (6922)
- GENTILLY - 1 NUCLEAR POWER STATION.
- (b) Atomic Energy of Canada Limited.
- (d) Experimental and theoretical, design.
- (e) Former studies were devoted to studying the rate of dumping heavy water from the calandria into the dump tank. One of the requirements of the moderator system is that circulation of this water back to the calandria should continue through all modes of operation. This formed the subject of the present investigation, conducted in a model which reproduced to a scale of 1:5 the calandria annulus, the dump lines, the dump tank and a certain length of the pump suction line.
- (f) Completed.
- (h) Report submitted to sponsor.
- (6923)
- BURRITTS RAPIDS LOCK (RIDEAU CANAL).
- (b) Department of Transport, Canals Division, Ottawa.
- (d) Experimental.
- (e) Improvement of the filling system of this small lock (10.6 foot lift). The desired modifications have been evolved under steady flow conditions, at a scale of 1/20.
- (f) Completed.
- (g) Report submitted to sponsor.
- (6924)
- OUTARDES 2 POWER INTAKE.
- (b) Hydro-Quebec.
- (d) Model investigation, design.
- (e) Model tests at scale 1/88. Head losses were studied for different intake channel excavations. Vortexes which formed under certain conditions were eliminated.
- (f) Completed.
- (h) Report submitted to sponsor.
- (6925)
- ROSETON GENERATING STATION.
- (b) Babcock & Wilcox Canada Limited; Burns & Roe, Consulting Engineers, New York.
- (d) Model investigation, design.
- (e) Model testing of the intake structure, at scale 1/30, aimed at verifying that the flow of water to the pumps would not be hindered by the existence of air entraining vortexes or other adverse flow characteristics, and to observe the general behaviour of the flow when various combinations of chambers and pumps are in use.
- (f) Completed.
- (h) Report submitted to sponsor.
- (6926)
- OUTARDES 4 - TUNNEL CLOSURE.
- (b) Hydro-Quebec.
- (d) Experimental and design.
- (e) Investigation of the possibilities of closing the diversion works by blasting a rock plug. Following a partial closure from the plug blast, study of different ways to assure complete closure (model at a scale of 1/48).
- (f) Completed.
- (h) Report submitted to sponsor.
- (6927)
- WELLAND CANAL - BANK PROTECTION.
- (b) The St. Lawrence Seaway Authority, Montreal.
- (d) Experimental and design.
- (e) Study of stone protection against damage to canal banks resulting from waves produced by passing vessels (scale 1/60).
- (f) Completed.
- (h) Report submitted to sponsor.
- (6928)
- WELLAND CANAL - HAWSER PULLS.
- (b) The St. Lawrence Seaway Authority, Montreal.
- (d) Experimental and design.
- (e) Study on a 1/60 scale model of the forces induced in the hawsers of moored ships caused by wakes of passing vessels.
- (f) Completed.
- (h) Report submitted to sponsor.
- (6929)
- NAVIGATION CANAL - SHIP WAVES.
- (d) Model investigation.
- (e) General investigation of ship waves in navigation canals. Determination of wave heights and patterns as functions of ship speed, displacement and location in canal.
- (6930)
- VANCOUVER HARBOUR - BURRARD INLET CROSSING.
- (b) National Harbour Board.
- (d) Model investigation.
- (e) Model to study the effect of the approach causeway for the crossing of Burrard Inlet on the current patterns and velocities in the area of Coal Harbour Basin. Investigation of the rate of water exchange taking place in the basin and effect of Brockton Point sewage outfall flow on water quality.
- (f) Completed.
- (h) Report submitted to sponsor.
- (6931)
- BUBBLER ACTION ON FLOATING BODY.
- (d) Model investigation.
- (e) Investigation on the possibilities of moving a floating body (ship, for example) by adequate disposition of bubble curtains. Applications to locks, docks, turning basins, etc.
- (6932)
- MACAULAY POINT OUTFALL - VICTORIA.
- (b) Associated Engineering Services.
- (d) Experimental, design.
- (e) Tests in glass-sided flume to determine movement characteristics of sediments on the sea bed where the outfall is to be built. Sediments evaluated first, then studies done to determine effects on outfall pipe, rate of scour and sinking of pipe.
- (f) Completed.
- (h) Report presented to sponsor.
- (6933)
- FIRST NARROWS CROSSING TUNNEL.
- (b) C.B.A. - Swan Wooster, Consultant.
- (d) Experimental, development.
- (e) An existing distorted model of the Port of Vancouver (1/600 horizontal scale, 1/150 vertical scale) was used to do several studies concerning the proposed tunnel: detailed tidal velocity patterns in the tunnel area, with prototype checks on some points: rate of water exchange in Coal Harbour by tidal action; effect on water

quality in the harbour of the Brockton Point sewage outfall under tidal flows.

- (f) Completed.
- (h) Several reports presented to client.

(6934)

JORDAN RIVER REDEVELOPMENT.

- (b) International Power and Engineering Consultants and British Columbia Hydro-Power Authority.
- (d) Experimental, design.
- (e) Scale model study of the powerhouse tailrace which must also accept rapid discharge changes from a pressure relief valve. Modifications to original design to avoid flow congestion in the tailrace. Means were found to remove disturbances to the turbine draft-tube discharge, as well as eliminating currents which drew gravel onto the concrete from the riverbed downstream.
- (f) Completed.
- (h) Report presented to sponsor.

LAVAL UNIVERSITY, Department of Mechanical Engineering, Quebec 10, P.Q., CANADA. Dr. C. I. H. Nicholl, Department Head.

(6935)

JET-FLAP EFFECT ON SUPERCAVITATING FLOW.

- (b) Defence Research Board of Canada.
- (d) Theoretical and experimental investigation of a basic nature, with practical applications.
- (e) Study of the performance of trailing edge jet-flap in supercavitating hydrofoil with particular attention to the influence of tunnel wall and free boundary effects.
- (g) Experimental data at small cavitation number showed the effects of jet-flap on lift coefficient are much less than that predicted by linearized theory available for zero cavitation number.
- (h) "Some Experiments on a Supercavitating Plane Hydrofoil With Jet-Flap." Nguyen Ngoc Dinh, J. of Ship Research, Vol. 13, No. 3, pp. 207-219, Sept. 1969.

UNIVERSITY OF MANITOBA, Department of Civil Engineering, Hydraulics Laboratory, Winnipeg 19, Manitoba, CANADA. V. Galay, Assistant Professor.

(6619)

ENGINEERING INTERFERENCE WITH RIVERS.

- (d) Field investigations; applied research for M.Sc. thesis.
- (e) To quantitatively and qualitatively assess the effects of engineering interference, such as dams and diversions, upon the behaviour of a river channel. Field work is presently being concentrated on the Seine River Diversion Channel which has undergone extensive erosion.
- (g) Field surveys have been completed on the Seine River Diversion, indicating that the slope of the channel was too steep. Studies to stabilize the channel are continuing.
- (h) "Degradation of the Seine River Diversion Channel." O. Caron, M. Sc. thesis, 1970.

(6936)

GABION DROP STRUCTURES.

- (b) Water Control and Conservation, Province of Manitoba.
- (d) Field and laboratory; applied research.
- (e) Investigation into the best arrangement of gabion baskets in drop structures. The extent of scour

downstream of the structure was investigated and adequate protection developed.

- (g) Gabion drop structures found to perform well; arrangement is flexible and variations are being investigated further on the Graham Creek Diversion Channel.
- (h) "Hydraulic Model Studies of Gabion Structures on Graham Creek." V. J. Galay, Report to Province of Manitoba, 1970.

(6937)

LAKE WINNIPEG EROSION STUDIES.

- (d) Field and laboratory; applied research.
- (e) Investigation into the extent of beach erosion along the east and west shorelines of Winnipeg Beach. Protective measures at Winnipeg Beach are now being investigated in a hydraulic model.
- (g) Field investigations indicated a general south-easterly movement of sand.
- (h) "Shoreline Processes on Lake Winnipeg." W. M. Veldman, M. Sc. thesis, 1969.

MCGILL UNIVERSITY, Department of Civil Engineering and Applied Mechanics, Montreal 2, P.Q., CANADA. S. B. Savage, Assistant Professor.

(4546)

CAVITATION AT HIGH-HEAD SLUICE GATES.

- (b) National Research Council, Canada.
- (c) Dr. A. J. Reynolds.
- (d) Experimental; applied research, for doctoral degree.
- (e) Study of pressure fluctuations on wall behind an obstruction which produces cavitation.
- (f) Work transferred to 11" by 11" water tunnel.
- (g) The flow was established in a syphon tunnel of section 3" by 3". Mean pressure distributions were measured for a wide range of blockage ratios, with and without air addition. Overall pressure recovery was found to be accurately predicted by momentum balance assuming one-dimensional flow. Length of eddy behind gate (without air addition) agreed with previous measurements of Rouse and Forthmann. Measurements of pressure fluctuations in reattaching flow in the absence of cavitation have been carried out in a wind tunnel.
- (h) "Pressure Fluctuations in Reattaching Flow," R. Narayanan and A. J. Reynolds, J. Hydraulics Div., Proc. ASCE, Vol. 94, No. HY6, p. 1383, 1969. "Reattachment Downstream of a Control Gate," A. D. Kapur and A. J. Reynolds, J. Hydraulic Res., Vol. 5, No. 1, p. 1, 1967.

(5280)

UNIFORM DISTORTION OF TURBULENCE.

- (b) Defence Research Board, Canada.
- (c) Dr. A. J. Reynolds.
- (d) Experimental; basic research for doctoral thesis.
- (e) Study of uniformly distorted turbulence to investigate the approach to equilibrium structure and the nature of that structure.
- (g) Several distorting ducts have been constructed, to allow both planar and three-dimensional irrotational straining of grid turbulence. The case of plane straining has been studied in detail, the turbulence being found to respond in two respects in a manner markedly different from that reported by Townsend. The degree of anisotropy attainable is much greater; the relaxation of anisotropy upon release of the strain is much more abrupt.
- (h) "The Distortion of Turbulence by Irrotational Plane Strain," H. J. Tucker and A. J. Reynolds,

(5669)

GENERATION OF SURGES AND SOLITARY WAVES.

- (b) National Research Council, Canada.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) Study of the generation and development of waves by a single stroke of a piston at uniform velocity.
- (g) Time histories of channel bed pressures and free surface elevations are being measured. The higher-order equations accounting for the effects of nonlinearity and dispersion are being integrated by the method of characteristics, and by finite difference methods. Effect of wall friction on wave development is being studied.

(6610)

SUPERCAVITATING LOW ASPECT RATIO HYDROFOILS.

- (b) National Research Council, Canada.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) Study of the flow about low aspect ratio supercavitating hydrofoils.
- (g) Three-component measurements are being carried out on models tested in the 11" x 11" cavitation tunnel.

(7013)

MIGRATION OF PARTICLES IN POISEUILLE FLOW.

- (b) National Research Council, Canada.
- (c) Dr. R. G. Cox.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) Study of the radial migration of suspended solid particles and immiscible fluid drops in a viscous fluid flowing along a circular tube with emphasis on the effect of the mutual interaction of such particles.
- (g) A mathematical theory has been found which describes some of the existing experimental results.

MCMASTER UNIVERSITY, Department of Civil Engineering and Engineering Mechanics, Hamilton, Ontario, CANADA.
Dr. Alan A. Smith, Associate Professor.

(7582)

PROBLEM ORIENTED COMPUTER SUB-ROUTINE LIBRARY FOR WATER RESOURCES.

- (d) Analytical and computational research.
- (e) Continued augmentation of a library of sub-routines for the solution of basic problems in steady, one-dimensional open channel flow. Extension to more general areas including unsteady flow and multi-dimensional situations.
- (g) A library in Algol has been completed. Translation to Fortran is in hand. Documentation is in course of preparation.
- (h) "Computational Procedures for Flow Resistance Laws." Alan A. Smith, J. Hydraulics Div., ASCE, Vol. 96, No. HY3, Proc. Paper 7142, March 1970, pp. 665-679.
"The Case for a Procedure Library in Water Resources." Alan A. Smith, J. Hyd. Research, 8 (1970) No. 1, pp. 89-108.
"A Problem-Oriented Library for Steady, One-Dimensional Open-Channel Flow." Alan A. Smith, Ph.D. thesis (1969), Strathclyde Univ., Glasgow, U. K.

(7583)

MATHEMATICAL MODELING OF CRITICAL FLOW TRANSITIONS.

- (d) Analytical, computational and experimental

research for master's project.

- (e) Comparison is made between observed behaviour and numerically predicted behaviour of open-channel flow transitions involving a critical section in which a one-dimensional approximation is not admissible.
- (g) Theoretical aspect is developmental; experimental work in preliminary stages.

MCMASTER UNIVERSITY, Department of Chemical Engineering, Fluid Mechanics Group, Hamilton, Ontario, CANADA.
Dr. A. E. Hamielec, Associate Professor.

(6056)

VISCOUS FLOW THROUGH PARTICLE ASSEMBLAGES.

- (b) National Research Council of Canada.
- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) Project is aimed at developing computer solutions of the Navier-Stokes equations for transient, incompressible flow through particle assemblages (fluidized and packed beds and bubble swarms) at intermediate Reynolds numbers. New techniques are being developed to account for particle interaction.
Experimental work involves the measurement of the surface pressure distribution on a test sphere in a packed bed.
- (g) Numerical solutions have been obtained for incompressible, Newtonian flow through sphere and cylinder assemblages for $Re = 0-1000$ and porosity, $0.4-1.0$.
Numerical solutions have been obtained for a single accelerating sphere using an accelerating frame of reference. This has permitted the calculation of transient stream function and vorticity distributions. The agreement with experimental drag data is excellent.
- (h) "Viscous Flow Through Particle Assemblages at Intermediate Reynolds Numbers, Part I - Steady State Solutions for Flow Through Assemblages of Spheres," B. P. LeClair and A. E. Hamielec, I&EC Fundamentals, 7, 542 (1968), and "Numerical Studies of Viscous Flow Around Circular Cylinders," A. E. Hamielec and J. D. Raal, Physics of Fluids, 12, 11 (1969).
Other papers on cylinders, spheres (solids and fluid) are in press and may be obtained by writing Dr. A. E. Hamielec.

(6057)

VISCOUS FLOW AROUND BLUNT BODIES IN THE TRANSITION FLOW REGIME.

- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) Computer solutions for transient, three-dimensional flows around blunt object at high Reynolds numbers are being developed. Disturbances are introduced and the effects on local flow behaviour are predicted theoretically. Disturbance parameters such as position, wave form, frequency, amplitude, and damping factor are being considered. This investigation may lead to techniques for drag reduction. The experimental program is now being planned.
- (f) Suspended.

(6947)

VISCOUS FLOW AROUND BLUNT BODIES - METEOROLOGICAL APPLICATIONS.

- (c) Dr. A. E. Hamielec, and Dr. H. R. Pruppacher, Assoc. Prof., Dept. of Meteorology, Cloud Physics Laboratory, Univ. of Calif., Los Angeles, Calif.

- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) Measurement and prediction of transient and steady-state drag, internal circulation velocities in raindrops and velocities of approach of colliding drops.
- (g) It has been shown experimentally and by numerical calculations that as the Reynolds number approaches zero, the drag on a sphere approaches zero via the Oseen drag rather than via the Stokes drag. A relationship between "drag regime" and flow pattern has been established for flow around a single sphere or cylinder. Numerical solutions of simultaneous free and forced convection around a single sphere have shown that at low Reynolds and Prandtl (Schmidt) numbers the drag is a very strong function of Grashof number.
- (h) "A Numerical Study of the Drag on a Sphere at Low and Intermediate Reynolds Numbers." B. P. LeClair, A. E. Hamielec, and H. R. Pruppacher. To be published in J. Atmospheric Sciences. "Some Relations Between Drag and Flow Pattern of Viscous Flow Past a Sphere and a Cylinder at Low and Intermediate Reynolds Numbers." H. R. Pruppacher, B. P. LeClair and A. E. Hamielec. J. Fluid Mech., Vol. 44, 4, 1970, pp. 781-790. "Simultaneous Free and Forced Convection Around a Single Sphere." S. Woo and A. E. Hamielec. Submitted to J. Mechanics and Appl. Physics (USSR).

(6948)

FLOW OF VISCOELASTIC FLUIDS.

- (b) National Research Council of Canada.
- (c) Dr. A. E. Hamielec and Dr. J. Vlachopoulos.
- (d) Theoretical and experimental; basic research for doctoral thesis.
- (e) Project is aimed at developing constitutive equations for flow of polymer melts with due regard to distribution of molecular weight, branching and chain degradation.

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NATIONAL RESEARCH COUNCIL, Division of Mechanical Engineering, Hydraulics Section, Montreal Road, Ottawa 7, CANADA. Dr. S. Ince, Section Head.

(4525)

FORMATION OF ICE IN RIVERS.

- (d) Experimental field investigation, applied research.
- (e) Study of the thermal balance and winter regime of rivers, ice movement and its effect on navigation and flooding with a particular view of extending the winter navigation season.
- (h) "A Study of the Thermal Balance of the St. Lawrence River by Digital Simulation." M. Majewski, S. Ince and E. R. Funke, NRC Report LTR-HY-5, 1970.

(6602)

TIDAL HYDRAULIC MODEL OF ST. LAWRENCE RIVER AND ESTUARY.

- (b) Department of Transport, Canada.
- (c) Mr. J. Ploeg.
- (d) Experimental, applied research.
- (e) A hydraulic model of the tidal reach of the river has been constructed and calibrated for the study of navigation improvements.
- (h) "Comprehensive Tidal Study of the St. Lawrence River." J. Ploeg and J. W. Kamphuis, Proc. 11th Conf. Coastal Engrg., London, 1968.

(6603)

MATHEMATICAL MODEL OF THE ST. LAWRENCE RIVER AND ESTUARY.

- (d) Theoretical; applied research.
- (e) Finite difference and finite element methods of calculating tide propagation in the St. Lawrence River.
- (h) "Comprehensive Tidal Study of the St. Lawrence River." J. Ploeg and J. W. Kamphuis, Proc. 11th Conf. Coastal Engrg., London, 1968.

(7094)

LITTORAL DRIFT PROBLEMS AT VISAKHAPATNAM, INDIA.

- (b) Howe (India) Private Limited, New Delhi.
- (d) Experimental; design purposes.
- (e) Fixed and movable bed studies to determine deposition and erosion patterns for a new harbour development and to suggest methods of sand bypassing and erosion control.

(7095)

MATHEMATICAL MODEL OF THE LOWER FRASER RIVER.

- (d) Theoretical; applied research.
- (e) Finite difference explicit method of calculating tide propagation in the Lower Fraser River to determine navigation improvements.

(7096)

NON-LINEAR WAVE INTERACTIONS.

- (c) Dr. J. E. Feir.
- (d) Experimental, theoretical; basic research.
- (e) Investigation is a sequel to an earlier study by Benjamin and Feir on the instability of progressive deep water waves with special attention to the generation of complex wave fields by non-linear interaction of small side-band disturbances with an initially regular train of steep waves.
- (h) "The Disintegration of Wave Trains on Deep Water." Benjamin T. Brooke and J. E. Feir, J. Fluid Mechanics, Vol. 27, Pt. 3, pp. 417-430, 1967.

(7097)

GENERATION OF HOMOGENEOUS TURBULENT SHEAR FLOW.

- (c) Dr. L. Lau.
- (d) Experimental; basic research.
- (e) The concept of homogeneous turbulence in a shear flow has been the subject of numerous analyses. However, the problem of actually generating a homogeneous shear flow has not been completely overcome. It is hoped that a curved screen placed in a wind tunnel could generate the desired flow characteristics.
- (h) "Flow of Stratified Fluid Through Curved Screens." Y. L. Lau, W. D. Baines, J. Fluid Mech., Vol. 33, Pt. 4, pp. 721-738, 1968.

(7098)

WAVE DIRECTION STUDY.

- (c) Mr. J. Ploeg.
- (d) Field study, theoretical; basic research.
- (e) Using a triangular array of wave sensors in deep water in Lake Ontario, Ontario, measurements are being made to determine the direction of propagation of wind generated waves and to calculate the actual wavelengths, corresponding to peaks in frequency spectrum.

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UNIVERSITY OF NEW BRUNSWICK, Department of Civil Engineering, Fredericton, N.B., CANADA. Professor Sam Shulits.

(6949)

RESERVOIR AGGRADATION.

- (d) Analytical; applied research; design; master's thesis.
- (e) Application of bedload formulas, particularly Schoklitsch's, to compute: (1) the deposition in a reservoir; (2) the downstream and upstream growth of the deposition. Results will be compared with measured aggradation in certain reservoirs.

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QUEEN'S UNIVERSITY AT KINGSTON, Department of Civil Engineering, Hydraulic Laboratory, Kingston, Ontario, CANADA. Dr. Arthur Brebner, Laboratory Head.

(5673)

THE ATTENUATION OF WATER WAVES BY A FLOATING PULPWOOD BREAKWATER.

- (b) The Pulp and Paper Research Institute of Canada.
- (c) Professor R. J. Kennedy.
- (d) Experimental and field project.
- (e) The attenuation of waves of various size and steepness by log masses of different characteristics was measured in the laboratory and in the field.
- (f) Completed.
- (g) "Flexible Porous Breakwaters." R. J. Kennedy and J. Marsalak, pp. 1095-1103, Proc. Eleventh Conf. on Coastal Engrg., London, September 1968.

(5674)

STUDIES OF FLOW-THROUGH VORTICES.

- (b) The National Research Council of Canada.
- (c) Dr. J. D. Boadway.
- (d) Experimental and theoretical project for master's and doctoral theses.
- (e) Velocities, pressures and turbulence characteristics in a series of closed flow-through vortex chambers are being measured by photographic and electronic techniques.
- (f) Completed.
- (g) A departure from free vortex form has been observed, most of which has been explained by analysis using Reynolds equation in cylindrical coordinates.
- (h) "Instrument for Measuring Fluid Pressures at a Solid Boundary." J. D. Boadway and R. J. Kennedy. Rev. of Sci. Instruments, Vol. 39, No. 3, 389-393, March 1968.

(6494)

FLOATING AND SUBMERGED BREAKWATERS.

- (b) National Research Council of Canada; Federal Department of Public Works.
- (d) Experimental and laboratory.
- (e) Attenuation of waves by sundry floating structures and by submerged structures of various configurations.
- (f) Completed.
- (h) "Floating Breakwaters." Brebner and Ofuya, Proc. 11th Conf. Coastal Engineering. "Solid and Permeable Submerged Breakwaters." Dick and Brebner, Proc. 11th Conf. Coastal Engrg.

(6495)

MAGNITUDE AND PROBABILITY OF PEAK FLOWS ON SMALL DRAINAGE BASINS IN SOUTHERN ONTARIO.

- (b) The National Research Council of Canada.
- (c) Dr. W. E. Watt.

- (d) Experimental and theoretical project; applied research for master's and doctoral theses.
- (e) Development of a procedure for evaluating the peak flow which corresponds to a particular return period for small ungauged drainage basins.
- (h) "A Peak Discharge Relation for Intermediate Drainage Basins." W. E. Watt and R. J. Kennedy, Water Resources Research, Vol. 5, No. 6, pp. 1406-1409, December 1969.

(6497)

THE CONTROL OF VELOCITY DISTRIBUTION IN A VORTEX.

- (b) The National Research Council of Canada.
- (c) Dr. J. D. Boadway.
- (d) Experimental and theoretical project; applied research for a master's thesis.
- (e) An attempt to develop a hydraulic design to produce a vortex with the best sedimentation characteristics.
- (g) A mechanical hydraulic system has been developed which produces a forced vortex of moderate rate of rotation and is suitable for sedimentation.
- (h) Two master's theses have been written on this development.

(6498)

WATER CLARIFICATION.

- (b) Department of University Affairs of the Province of Ontario.
- (c) Dr. J. D. Boadway.
- (d) Experimental and theoretical project; applied research for a master's thesis.
- (e) A study of sedimentation with centrifugal acceleration.
- (g) An algorithm has been developed, using a probabilistic model, to predict sediment in a centrifugal field in the presence of turbulence. Practical sedimentation tests results give slightly lower separation than predicted by the above theory.
- (h) A master's thesis has been written on this work.

(6977)

THE SOURCE AREA FOR STORM RUNOFF.

- (b) Dept. of Energy, Mines and Resources, Canada.
- (c) Dr. W. E. Watt.
- (d) Experimental and theoretical project and field investigation.
- (e) The portion of the area of an intermediate drainage basin which contributes to direct runoff under different conditions (soil moisture, rainfall intensity, basin topography, etc.) will be determined.
- (g) A Ph.D. thesis is being prepared.

(6978)

WAVE FRICTION.

- (b) National Research Council of Canada.
- (d) Experimental.
- (e) Separation of side and bottom friction in wave attenuation in a two-dimensional flume.
- (h) Paper by Treloar and Brebner to be presented at Coastal Engineering Conference, 1970.

(6979)

BOUNDARY LAYER AND SEDIMENT TRANSPORT UNDER WAVES.

- (b) National Research Council of Canada.
- (c) Dr. J. W. Kamphuis.
- (d) Basic experimental and theoretical research toward Ph.D. degrees.
- (e) The turbulent oscillatory boundary layer below waves and sediment transport characteristics under wave action are measured in an oscillating water tunnel as well as under regular and irregular wave action in a wave flume.

(6980)

DISTRIBUTION OF SEDIMENT CARRIED IN SUSPENSION.

- (b) National Research Council of Canada.
- (c) Prof. Dr. M. S. Yalin.
- (d) Theoretical and experimental; Ph.D. thesis.
- (e) The knowledge on the distribution of concentration of sediment carried by the flow along the flow depth gives the possibility for determining the total transport rate in a river or channel; it directs the design of water intake structures, and determines the schemes related to the river training works.
- (g) The theoretical analysis, which rests on a probabilistic basis, is accomplished. The distribution curves obtained are consistent with the experimental data so far available. A ten-page summary of the analysis forms the end part of chapter VI, "Mechanics of Sediment Transport," M. S. Yalin, Pergamon-Press, Oxford, England.

(6981)

TIDAL COMPUTATIONS IN ESTUARIES.

- (b) National Research Council of Canada.
- (c) Dr. J. W. Kamphuis.
- (d) Applied computer study toward master's degree.
- (e) Proper use of the implicit finite difference scheme and the method of characteristics are investigated.
- (h) "Comprehensive Tidal Study of the St. Lawrence River." J. Ploeg and J. W. Kamphuis, 11th Coastal Engrg. Conf., London, 1968, p. 1421.
- "Mathematical Tidal Study of the St. Lawrence River," J. W. Kamphuis, Proc. ASCE, Vol. 96, No. HY3, March 1970, pp. 643-664.

(6982)

LANDSLIDE GENERATED WAVES.

- (b) National Research Council of Canada.
- (c) Dr. J. W. Kamphuis.
- (d) Basic experimental and theoretical research towards master's degree.
- (e) The height, energy and velocity of propagation of waves generated by a model landslide are measured and systematic analysis is performed.
- (g) M.Sc. thesis is in preparation.
- (h) "On Water Waves Generated by Landslides." L. Law and A. Brebner, Third Australasian Conf. on Hydraulics and Fluid Mechanics, Sydney, 1968, pp. 155-159.
- "Impulse Waves," J. W. Kamphuis and R. J. Bowering, 12th Coastal Engrg. Conf., Washington, 1970 (to be published).

(6983)

TEMPERATURE GRADIENTS IN NATURAL ICE SHEETS.

- (b) National Research Council of Canada.
- (c) Professor S. S. Lazier.
- (d) A theoretical study combined with a field project for master's thesis.
- (e) The forces exerted by an ice sheet due to thermal expansion are dependent on the thermodynamic history of the sheet. This study is an attempt to acquire more insight into these forces by comparing theoretical temperature gradients, derived from principles of heat transfer, with those measured in an actual ice sheet. A station was set up on the ice of Kingston Harbour and continuous records of solar radiation and temperature gradients were taken, along with other pertinent variables.
- (g) The temperature gradients measured were quite different from those assumed in the literature and used for calculation of forces.
- (h) "Movements in Continuous Ice Sheets and Temperature Gradients in Ice Sheets," S. S. Lazier and F. A. MacLachlan. Read at National Research Council

Symp. on Snow and Ice, Calgary, Nov. 1969. Proceedings in press, available from Division of Building Research, National Research Council.

(6984)

DISCONTINUITIES IN CONTINUOUS ICE SHEETS.

- (b) National Research Council of Canada.
- (c) Professor S. S. Lazier.
- (d) A field investigation, coupled with a theoretical study for a doctorate thesis.
- (e) Not infrequently ice sheets on lakes of moderate size buckle and heave up, forming "pressure ridges." Obviously this phenomenon is caused by thermal expansive forces, and this study is concerned with the mechanics for the formation of such "ridges" and the conditions necessary to sustain their growth. Hopefully, a combination of theoretical analysis and field experiments will throw some light on this phenomenon and, as well, onto the general problem of the expansive forces exerted by static ice sheets.
- (f) Observation of pressure ridges and movements of the ice sheet on either side of ridges has been underway for three years.

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UNIVERSITY OF SASKATCHEWAN, Department of Civil Engineering, Hydraulics Laboratory, Saskatoon, Saskatchewan, CANADA. Professor C. D. Smith.

(6483)

FLOW MEASUREMENT USING TRIANGULAR WEIRS AND FLUMES.

- (b) International Hydrological Decade.
- (d) Theoretical and experimental; M.Sc. thesis.
- (e) A study of the effect of crest length and submergence on the discharge coefficients for a V-notch broad-crested weir.
- (f) Completed.
- (h) "Triangular Broad-Crested Weir." C. D. Smith and W. S. Liang, J. Irrigation and Drainage Division, ASCE, Dec. 1969.

(7091)

PIPE DROP STRUCTURES.

- (b) Conservation and Development Branch, Department of Agriculture, Saskatchewan.
- (d) Laboratory experimental project; M.Sc. thesis.
- (e) The study was concerned with the development from models of pipe drop structure for use by the Conservation and Development Branch on the South Saskatchewan Irrigation Project.
- (f) Completed.
- (g) The pipe slope recommended was 2 horizontal to 1 vertical, and satisfactory energy dissipation was achieved within the pipe by using a system of multiple orifices.
- (h) "Pipe Drop Structures." M. Sc. thesis by P. D. Wang, 1969, Univ. of Sask., Saskatoon.

(7092)

SQUARE CONDUIT OUTLET STRUCTURE.

- (b) National Research Council.
- (d) Laboratory experimental project; M. Sc. thesis.
- (e) The question of adapting existing designs currently used with round pipes to the case of square pipes was investigated. In particular, the performance of the USBR impact basin and a straight walled diverging transition with hydraulic jump stilling basin was studied.
- (f) Completed.
- (g) The USBR impact basin produced a high hydraulic grade line at the outlet and a poor flow distribution. The structure was modified to improve flow distribution. Qualified design recommendations were made for both outlet structures.
- (h) "Square Conduit Outlet Structures." M.Sc. thesis

(7093)

HYDRAULIC JUMP IN SLOPING CIRCULAR PIPES.

- (b) National Research Council.
- (c) Laboratory experimental project; M.Sc. thesis.
- (e) Studies are being made to check the application of the momentum equation to the hydraulic jump in a sloping circular pipe, in which the pipe flows full downstream from the jump. The variables considered include gate opening, head, slope, air flow, and tailwater depth.

UNIVERSITY OF TORONTO, Department of Chemical Engineering and Applied Chemistry, Toronto 181, Ontario, CANADA. Professor J. G. Breckenridge, Dept. Head.

(6950)

IMPINGING JET STUDIES.

- (c) Dr. Olev Trass, Professor.
- (d) Experimental and theoretical studies for graduate theses, basic research.
- (e) Velocity profiles, turbulence and boundary layer development for liquid and gas jets impinging on flat surfaces. Pressure distributions and local mass transfer rates at the surface. Application to heat and mass transfer situations of academic as well as industrial interest.
- (f) Laminar jet study completed.
- (g) Theoretical solution and experimental verification of flow and wall mass transfer in impinging laminar jets originating with Poiseuille flow. (Ref. 2).
- (h) "Mass Transfer in a Turbulent Radial Wall Jet." D. A. Dawson and O. Trass, Can. Jour. Chem. Eng. 44, 6, 121-129, 1966.
"Mass Transfer in a Nonuniform Impinging Jet. Part I. Stagnation Flow - Velocity and Pressure Distribution; Part II. Boundary Layer Flow - Mass Transfer." AIChE J. 16, 1, 82-96, 1969.

(6951)

ROUGH SURFACE TRANSFER.

- (c) Dr. Olev Trass, Professor.
- (d) Mainly experimental studies for graduate theses, basic research.
- (e) Flow patterns and mass transfer at surfaces having various types and sizes of roughness. To elucidate influence of roughness patterns on momentum, heat and mass transfer.
- (g) Some mass transfer results for random and regular V-groove roughnesses.

(6952)

FLUID FLOW STUDIES BY PHOTOCROMIC DYE TECHNIQUE.

- (c) R. L. Hummel, Assoc. Prof; J. W. Smith, Assoc. Prof. and Asst. Dept. Head; M. E. Charles, Assoc. Prof.
- (d) Experimental, basic and applied research, for Ph.D., M.A.Sc., postdoctorals and technical assistance.
- (e) During the past few years, a new technique has been developed in our laboratories for the measurement of fluid movement which does not disturb the flow and which yields instantaneous velocity profiles rather than the point values of current techniques. In this technique, a dye indicator, for example, 2-(2'-dinitrobenzyl) pyridine is converted from an almost colourless substance to one which is deep blue by a beam of ultraviolet light. Within a second or two the dye will revert to its original colourless form, but

the colour remains strong enough for accurate velocity measurements to be made using a high speed camera. The dye trace is produced by a beam of ultraviolet light which is generated in a giant ruby pulse laser with harmonic generator. The usefulness of this technique has been proved, and a number of research publications on the behaviour of turbulent flows, flow in pipe jets, flow in fluidized beds, and other geometries have been obtained. In particular, a new research apparatus has been constructed for the study of flows around and over the surfaces of submerged objects. The first object studied has been a sphere, and the dye trace obtained is illustrated in a series of photographs. By examining such a series of such photographs, and knowing the time interval between the frames, a complete velocity profile of the flow can be obtained which shows the true fluid motion and in which the fluid flow has not been disturbed in any way by the velocity measuring device.

- (h) "A New Method for Non-Disturbing Turbulent Flow Measurements Very Close to a Wall." A. T. Popovich and R. L. Hummel. Chem Eng. Sci., 22, 21 (1967).
"Experimental Study of the Viscous Sublayer in Turbulent Pipe Flow." A. T. Popovich and R. L. Hummel. A.I.Ch.E. J., 13, 854 (1967).
"Nondisturbing Tracer Technique for Quantitative Measurements in Turbulent Flow." F. Frantisak, A. Iribarne, J. W. Smith and R. L. Hummel. I. and E. C. Fundamentals, 8, No. 1, 160 (1969).
"Transition and Turbulent Flow Parameters in a Smooth Pipe by Direct Flow Visualization." A. Iribarne, R. L. Hummel, J. W. Smith and F. Frantisak. Chem. Eng. Prog. (Symposium Series) 65, No. 91, 60 (1969).
"Statistical Analysis of Fluid Flow Fluctuations in the Viscous Layer Near a Solid Wall." A. T. Popovich. I. and E. C., 8, No. 4, 605 (1969).
"Average Velocity Distributions Within Falling Liquid Films." F.C.K. Ho and R. L. Hummel. Paper accepted Chem. Eng. Sci. Journal.
"The Velocity Distribution in the Turbulent Transition Region in Smooth Pipes." F. Frantisak, A. Iribarne, J. W. Smith and R. L. Hummel. Submitted to Chem. Eng. Sci. (Feb. 1970).
"An Experimental Study of Instabilities and Other Flow Properties of a Laminar Pipe Jet." A. Iribarne, F. Frantisak, R. L. Hummel and J. W. Smith. Submitted to J. Fluid Mechanics (1970).
"Turbulent Momentum Transfer in Rough Pipes." S. G. Dunn and J. W. Smith. Submitted to Chem. Eng. Sci. (1970).

UNIVERSITY OF TORONTO, Department of Civil Engineering, Toronto 5, CANADA. Department Head.

(7455)

WATER DISTRIBUTION SYSTEM ANALYSIS.

- (b) City of Toronto.
- (c) Profs. G. W. Heinke and R. A. Collins.
- (d) Theoretical and field investigation; applied research for master's thesis.
- (e) Development and testing of computer programmes suitable for analysis of large-scale water distribution systems. Done in cooperation with the City of Toronto.

UNIVERSITY OF TORONTO, Department of Geography,
Toronto 5, CANADA. Professor A. V. Jopling.

(7456)

LABORATORY RIVER-DELTA SYSTEM.

- (d) Experimental; basic research in fluvial geomorphology.
- (e) Small-scale experiments on the effects of sediment type on the pattern and geometry of stream and delta development; effects of base level change on the mode of aggradation and degradation in the system.
- (f) Outdoor experimental facilities being established; some preliminary work done on three-dimensional deltas.

(7457)

MECHANICS OF MUDFLOWS.

- (d) Experimental and field; basic and applied research for doctoral thesis in geomorphology.
- (e) Factors affecting the movement of mudflows, including the transport of coarse debris; clastic fabrics produced by mudflows. The laboratory work is to be integrated with field studies in the Canadian Rockies.
- (h) Field work in progress; laboratory facilities being established.

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UNIVERSITY OF TORONTO, Great Lakes Institute,
Toronto 5, CANADA. Professor G. K. Rodgers.

(7458)

THERMAL STRUCTURE, HEAT STORAGE AND EVAPORATION FOR LAKE ONTARIO.

- (b) Inland Waters Branch, Dept. of Energy, Mines and Resources, National Research Council, and Meteorological Branch, Dept. of Transport.
- (d) Field study in basic research.
- (e) This is a general study of the thermal structure and heat content of a large, deep lake (Lake Ontario) being carried out through an intensive observation program. Particular aspects under investigation include forecast of "thermal bar" conditions, ice formation and break-up, computation of an analytic heat budget for comparison with lake temperatures and evaporation estimates.
- (g) A prediction scheme for the time of disappearance of the thermal bar has been completed, as has been a computation of an analytic heat budget for four years. The model for analytic heat budget calculations is undergoing refinement.
- (h) "Heat Advection within Lake Ontario in Spring and Surface Water Transparency Associated with the Thermal Bar." G. K. Rodgers. Proc. 11th Conf. Great Lakes Res., 1968 (480-486), Internat. Assoc. Great Lakes Res.

(7459)

A STUDY OF LAKE CIRCULATION ON THE METROPOLITAN TORONTO WATERFRONT.

- (b) Ontario Water Resources Commission.
- (d) Applied research.
- (e) The study involves analysis of a number of time-series observations of currents near the shore in the open lake, investigation of harbour flushing and surges in the harbour entrances, entrainment of runoff behind the thermal bar and upwelling.
- (f) The major field work will be completed in 1970 and reports will be completed by early 1971.
- (g) Results to date indicate that good forecasts of current speed and direction can be based on wind observations alone. Some persistent current

independent of local winds appears to be also present.

- (h) "The Currents in the Toronto Region of Lake Ontario." P. F. Hamblin and G. K. Rodgers. Great Lakes Inst., Univ. of Toronto, PR 29, July 1967.

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UNIVERSITY OF TORONTO, Department of Mechanical Engineering, Toronto 5, CANADA. Professor C. Ross Lord, Department Head.

(1298)

DISCHARGE CHARACTERISTICS OF WEIR-TYPE SPILLWAYS.

- (c) Prof. L. E. Jones.
- (d) Experimental; applied research for master's theses.
- (e) A long-term research carried out with a view to systematizing discharge characteristics for spillways having various pier spacings and proportions.
- (g) Significant correlations obtained via special plotting techniques.
- (h) Report in preparation. Two oral presentations to conferences.

(2252)

HYDRAULIC FLOW IN OPEN CHANNELS OF VARIABLE SLOPE.

- (c) Prof. L. E. Jones.
- (d) Experimental; fundamental and applied research.
- (e) A doubly-tilting, variable-section flume facility of 166 ft. length is under construction. Provision is being made for a wide range of experimental conditions. Each half-channel can be tilted separately or both together, to $\pm 4\%$.
- (g) Novel design has permitted substantial economy in cost.

(5624)

OPEN-CHANNEL PROFILE ANALYSIS.

- (c) Prof. L. E. Jones.
- (d) Analytical; basic research.
- (e) Fundamental computational projects are being reviewed and investigated by computer analysis.
- (g) Improved extrapolation procedures indicate that significant accuracy of integration can be achieved with confidence and economy.
- (h) A critical review of current mathematical methods is in progress.

(5626)

FLOW IN A WEDGE WITH POROUS WALLS.

- (c) Prof. W. D. Baines.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) The flow of a fluid with a narrow wedge (less than 10 degrees included angle) is being investigated for walls made of screen. Pressure gradients and velocity distributions are being studied.
- (g) Peculiar characteristics have been found for flow approaching a screen at a small angle. Pressure drop is much greater than that predicted by simple theory.

(5627)

BUILDING AERODYNAMICS.

- (c) Prof. H. J. Leutheusser.
- (d) Experimental; for design purposes.
- (e) Determination of aerodynamic loading on high-rise buildings provided with exterior ribs and other architectural features.
- (h) "Influence of Architectural Features on the Static Wind Loading of Buildings." H. J. Leutheusser, Natl. Bureau of Standards, Building Science Series, Technical Meeting Concerning Wind Loads on Building and Structures, Jan., 1969.

(5629)

DYNAMICS OF TURBULENT LINE-VORTEX PAIR.

- (c) Prof. J. F. Keffer.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) Counter-rotating turbulent line vortices are convected by a free stream. The characteristics of turbulence, entrainment, velocity profiles and vortex interaction are being determined by conventional hot-wire anemometer equipment and visual techniques.
- (f) Completed.
- (h) "Swirling Turbulent Jet Flows, Parts I, II." B. D. Pratte and J. F. Keffer, UTME TP 6901 and 6906, 1969.

(5630)

PASSIVELY STRATIFIED FLOWS.

- (c) Professor J. F. Keffer.
- (d) Experimental and theoretical.
- (e) The influence of various flows upon distributions of passive scalar contaminants, i.e., low-level temperature, is being considered.
- (g) The influence of a turbulent wake upon a linear stratification has been completed. A self-preserving analysis has been developed to describe the results. A thermal mixing layer under the influence of an applied lateral strain is presently being analyzed.
- (h) "The Two-Dimensional Turbulent Wake in a Stratified Contaminant Field." C. C. Alexopoulos and J. F. Keffer, UTME TP 6810, 1968.

(5631)

INVESTIGATION OF PERIODICITY IN TURBULENT WAKES.

- (c) Prof. J. F. Keffer.
- (d) Experimental and theoretical; basic research.
- (e) Characteristics of turbulent wakes, with and without heated source, examined under influence of uniform lateral strain.
- (g) Results show self-preserving flow unstable to the applied strain.
- (h) "The Uniform Distortion of a Thermal Wake." J. B. Izatt and J. F. Keffer, UTME TP 7001, 1970.

(6002)

EFFECTS OF SKIN FRICTION ON PERFORMANCE OF HYDRAULIC JUMP.

- (c) Prof. H. J. Leutheusser.
- (d) Experimental; basic research for Master's thesis.
- (e) Effect of floor roughness on stationary hydraulic jumps in rectangular channels is being studied.
- (f) Suspended.
- (g) Characteristics of jump are determined by conditions of inflow.
- (h) "Effects of Inflow Conditions on the Hydraulic Jump." C. V. Kartha, M.A.Sc. thesis, Univ. of Toronto, 1968. Publications in preparation.

(6003)

SMOKE DIFFUSION FROM STACKS.

- (b) Contract research.
- (c) Prof. H. J. Leutheusser.
- (d) Experimental; applied research for design purposes.
- (e) Wind-tunnel study of stack discharge as affected by surrounding buildings.
- (g) Studies have proved effective means for determining chimney heights to prevent aerodynamic downdraft of stack effluents.
- (h) "Wind-Tunnel Modeling of Stack Gas Discharge." G. R. Lord and H. J. Leutheusser, Proc. Banff Conf. on Pollution, The Univ. of Calgary, 1968.

(6007)

FLOW-INDUCED VIBRATION OF BEAMS.

- (c) Prof. W. D. Baines.
- (d) Experimental and theoretical; applied research for doctoral thesis.
- (e) Controlled vibration of circular cylinders is being attempted by influencing the rate and location of separation. Interaction of the von Kármán trail and impulse at separation is being studied.

(6008)

PUMP AND PIPE SYSTEM TRANSIENTS.

- (c) Prof. L. E. Jones.
- (d) Analytical; applied research.
- (e) Computer solutions of equations for various combinations of pump and pipe characteristics.
- (g) Results to date indicate a significant effect caused by shape of characteristic curves. Special parametric plotting has permitted a distinctive assessment for pumped-storage reservoir filling time relative to pump characteristics.
- (h) "A Systematic Investigation of the Influence of Pump Characteristics upon Filling Time for a Given Reservoir." R. Portelli, B.A.Sc. thesis, Univ. of Toronto, 1970.

(6009)

PROBABILISTIC MODELS OF STORAGE RESERVOIRS.

- (c) Prof. V. Klemes.
- (d) Theoretical; applied research.
- (e) Probabilistic models of storage reservoirs are applied to the computation of various reliability characteristics, their distribution, and the analysis of accuracy, and to stationary solutions for correlated inputs and complex operating conditions.
- (f) Completed.
- (h) "Stationary Values of Characteristics of a Single Flow-Regulating Reservoir." V. Klemes, Vodohospodarsky casopis, Vol. 16, No. 2, pp. 170-181, 1968.
- "On Minimum Dimension of Transition-Probability Matrix in Moran's Storage Model." V. Klemes and L. E. Jones, Vodohospodarsky casopis, Vol. 17, No. 2, pp. 103-108, 1969.
- "Reliability Estimates for a Storage Reservoir with Seasonal Input." V. Klemes, J. Hydrology, Vol. 7, pp. 198-216, 1969. (In abbreviated form in Proc. Int. Hydrology Symp., Fort Collins, Colo., Sept. 1967).
- "A Two-Step Probabilistic Model of Storage Reservoir with Correlated Inputs." V. Klemes, Water Resources Res., Vol. 6, No. 3, pp. 756-767, 1970.

(6010)

LEAST-SQUARES FITTING OF RIVER RATING-CURVES.

- (c) Prof. L. E. Jones.
- (d) Analytical; applied research.
- (e) Proper attention to statistical weighting requires involved computing techniques. Suitable simple alternatives have been developed which have a wide applicability.
- (h) First paper submitted.

(6803)

CONVECTION IN A UNIFORM WATER LAYER BENEATH AN ICE SHEET.

- (c) Prof. W. D. Baines.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) Laboratory experiments on the conduction of heat between an ice layer and a parallel solid boundary through an intermediate layer of water have been completed.

- (f) *Neuring completion.*
- (g) Measurements of the temperature profiles throughout the water layer have been made and are compared with the results of a two-dimensional numerical analysis. The results are in good agreement.
- (h) Report in preparation.
- (6805)
FREE CONVECTION IN A VERTICAL CHANNEL.
- (c) Prof. I. G. Currie.
- (d) Experimental; basic research for Master's thesis.
- (e) Temperature and velocity measurements are being made in a vertical two-dimensional channel having heated walls. It is intended to establish profiles in the accelerating region of the flow.
- (f) Completed.
- (g) Extensive experimental data have been obtained and correlated.
- (h) "Natural Convection Between Isothermal Vertical Surfaces." I. G. Currie and W. A. Newman, Proc. IV Inter. Heat Trans. Conf., Paris, 1970.
- (6808)
WAKE OSCILLATIONS ON A VIBRATING CYLINDER.
- (c) Prof. I. G. Currie.
- (d) Experimental; basic research for Master's thesis.
- (e) Tests are being performed with a cantilevered circular cylinder which is vibrating in a uniform field. Measurements of the separation-point locations are being made and compared with the cylinder motion.
- (f) First phase complete.
- (g) Experimental data on instantaneous position of separation point have been obtained.
- (h) "Flow Separation on a Vibrating Circular Cylinder." V. C. Mei and I. G. Currie, Physics of Fluids, Vol. 12, No. 11, 2248-2254, 1969.
- (6809)
FLOW AROUND A SUBMERGED POROUS PLATE.
- (c) Prof. D. F. James.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) The flow around and through a screen partially filling a two-dimensional channel is being studied. The analysis predicts the downstream velocity profile for perpendicular and oblique screens having variable porosities.
- (6810)
QUANTITATIVE EVALUATION OF HYDROGEN-BUBBLE FLOW VISUALIZATION TECHNIQUE.
- (c) Prof. L. E. Jones.
- (d) Experimental; applied research.
- (e) Quantitative assessment of method for use in determining velocity distribution data.
- (g) Bubble buoyancy has significant effect. A calibration method has been developed whereby effective bubble diameter can be inferred from observations in a known velocity field.
- (h) Paper in preparation.
- (6811)
ENERGY LOSSES IN TWO-PHASE FLOW.
- (c) Prof. L. E. Jones.
- (d) Experimental and theoretical for Doctoral thesis.
- (e) Concerns flow of flashing fluid in horizontal circular pipe, to gain insight into development of two-phase single-component flow by studying pressure gradients, local void fractions and phase-velocities. Hot-film anemometer and high-speed photography to be used.
- (f) Experimental equipment completed and facilities installed for high-frequency data acquisition
- and real-time computer processing.
- (6812)
WALL JET FLOWS.
- (c) Prof. J. F. Keffer.
- (d) Experimental and theoretical; basic research for Master's thesis.
- (e) Mean flow and wall-shear characteristics for a jet discharging parallel to a wall are being investigated. In particular, the effect of a stepwise suction is being considered.
- (f) Completed.
- (h) "The Turbulent Wall Jet with Suction." T. B. Hedley, M.A.Sc. thesis, Univ. of Toronto, 1968.
- (6813)
GRID-PRODUCED TURBULENCE.
- (c) Prof. J. F. Keffer.
- (d) Experimental and theoretical; basic research for doctoral thesis.
- (e) The early decay period for the turbulent flow generated by a grid of parallel cylinders is being investigated. The mechanism by which the flow changes from a non-homogeneous to a homogeneous structure is under study.
- (g) Results show rapid approach to isotropy.
- (h) "Isotropy in Initial Period Grid Turbulence." E. A. Portfors and J. F. Keffer, Phys. of Fluids, 12, 1969.
- (6815)
DISCHARGE OF JETS INTO CROSS-WINDS.
- (c) Prof. J. F. Keffer.
- (d) Experimental and theoretical.
- (e) A mathematical model has been devised to predict the trajectory of a jet discharging at various angles into a uniform stream.
- (h) "Entrainment in Deflected Axisymmetric Jets at Various Angles to the Stream." J. L. Platten and J. F. Keffer, UTME TP 6808, 1968.
- (j) "The Physical Nature of the Subsonic Jet in a Cross-Wind." NASA Spec. Pub. SP-298, Oct. 1969.
- (6816)
WIND TUNNEL MODELING.
- (c) Prof. H. J. Leutheusser.
- (d) Experimental; basic research.
- (e) Development of boundary-layer-type velocity fields of significant size in wind tunnel to facilitate aerodynamic investigations of buildings and stack-gas discharge under realistic conditions.
- (g) Tests of smoke dispersion in non-uniform fields indicated effect of degree of boundary-layer immersion on plume behaviour.
- (6817)
TURBULENCE MEASUREMENTS IN WATER.
- (c) Prof. H. J. Leutheusser.
- (d) Experimental; basic research.
- (e) Application of hot-film anemometer to evaluation of turbulent quantities in open-channel flow phenomena.
- (g) First measurements of turbulence intensity inside hydraulic jump confirm (cf. Item 6002) significance of inflow conditions and suggest an effective jump length of about 30-times the sequent subcritical depth.
- (h) Papers in preparation.
- (7460)
ENTRAINMENT BY A PLUME AT AN INTERFACE.
- (c) Prof. W. D. Baines.
- (d) Experimental and theoretical.
- (e) The entrainment through the end of a buoyant plume or a jet striking a density interface is measured

- in small-scale experiments. Results should be applicable to pollution in the lower atmosphere.
- (f) Nearing completion.
 - (g) It has been shown that the entrainment rate is a function only of a local Froude number. Using measured values of this rate the density distribution in an enclosed box can be predicted. Results verify this theory.
 - (h) Report in preparation.
- (7461)
AERODYNAMIC OSCILLATIONS OF BLUFF CYLINDERS.
- (c) Prof. I. G. Currie.
 - (d) Theoretical and experimental.
 - (e) A basic study intended to better the understanding of the interaction between the fluid flow around an elastically supported body and the dynamic response of the body.
- (7462)
WAVES IN FLUIDS.
- (c) Prof. J. P. Dugan.
 - (d) Theoretical and experimental; basic research for Master's thesis.
 - (e) Various aspects of wave motion in fluids; reflection in continuously varying media; scattering; diffraction. Applications to electromagnetic, elastic, acoustic, gravity waves. Use of linear model for generating internal gravity waves by non-uniform heating. A 40 ft. x 2 ft. x 2 ft. internal and surface gravity wave tank is under construction.
- (7463)
CAVITATION INCIPIENCE IN PUMPING INSTALLATIONS FOR VARIOUS FLUIDS.
- (c) Prof. L. E. Jones.
 - (d) Analytical; applied research for Master's project report.
 - (e) Special plotting of available data for a considerable variety of fluids has confirmed the "principle of corresponding states" and indicates how experimental data, even though sparse, can be optimally exploited for wide use in practice.
 - (h) "Special Plottings for Denoting Cavitation Incipience with Various Fluids." L. E. Jones and T.-W. Cheung, 1970 Cavitation Forum, Joint Fluids Engrg., Heat Transfer and Lubrication Conf., ASME, Detroit, May 1970.
- (7464)
COMPUTER EVALUATION OF RAINFALL-RUNOFF CHARACTERISTICS, ROUGE RIVER BASIN, ONTARIO.
- (b) Collaborative with Dept. of Geography.
 - (c) Prof. L. E. Jones.
 - (d) Analytical; applied research for Master's thesis.
 - (e) Available records have been assembled for hourly intervals and give significant correlations.
 - (g) A derivative-time procedure has been developed which shows promise as a novel method of evaluating certain basic parameters.
- (7465)
STUDY OF WATER USAGE IN METROPOLITAN TORONTO.
- (c) Prof. L. E. Jones.
 - (d) Analytical; applied research for Master's thesis.
 - (e) Daily pumpage data have been computer-plotted and correlated with climatological data and with appropriate information on land use and occupancy.
 - (g) Significant patterns of behaviour, for the various city districts, provide a valuable means of assessing past performance and provide a rational basis for future requirements in prediction and potential rationing.
- (7466)
STREAMFLOW MEASUREMENT BY USE OF LASER DOPPLER ANEMOMETRY.
- (b) Collaborative with Inst. for Aerospace Studies.
 - (c) Prof. L. E. Jones.
 - (d) Experimental; basic research for Bachelor's and Master's theses.
 - (e) Laser light scattered from particles in a flowing stream can be beat against the direct radiation to produce a Doppler shift proportional to particle velocity and thus to stream velocity. Convenient positional adjustment and lack of physical encroachment provide considerable advantage.
- (7467)
INVESTIGATION OF AN AIR-CUSHION VEHICLE AS A HYDROGRAPHIC INSTRUMENT PLATFORM.
- (b) Collaborative with Inst. for Aerospace Studies and Dept. of Geography.
 - (c) Prof. L. E. Jones.
 - (d) Experimental and analytical; basic research for Bachelor's and Master's theses.
 - (e) Existing two-man vehicle to be redesigned and tested for performance and control.
- (7468)
ENERGY DISSIPATORS FOR STREAM DIVERSIONS.
- (b) Consulting assignment.
 - (c) Prof. L. E. Jones.
 - (d) Analytical and experimental; applied research.
 - (e) Urban development requires relocation of natural streams and significant energy dissipation.
- (7469)
BED-PACKING CHARACTERISTICS IN LOOSE-BOUNDARY HYDRAULICS.
- (b) Collaborative with Dept. of Geography.
 - (c) Prof. L. E. Jones.
 - (d) Experimental; applied research for Bachelor's and Master's theses.
 - (e) Influence of particle size and distribution on the flow-boundary location in an open channel is under study.
- (7470)
TURBULENT DIFFUSION IN DUCTS.
- (c) Prof. J. F. Keffer.
 - (d) Experimental and theoretical.
 - (e) A source of heat is introduced into a turbulent flow in a square duct. The mixing of heat via secondary flows and turbulent dispersion is analyzed.
- (7471)
WALL FLOWS WITH SUCTION.
- (c) Prof. J. F. Keffer.
 - (d) Experimental and theoretical; basic research for Doctoral thesis.
 - (e) The application of a step change in suction to a developed turbulent boundary layer is under investigation.
- (7472)
MATHEMATICAL MODELS OF RAINFALL-RUNOFF RELATIONS.
- (c) Prof. V. Klemes.
 - (d) Theoretical; basic research.
 - (e) Properties of probability distribution of runoff are studied as related to those of the distribution of precipitation. Also for the distributions of extreme values of runoff and precipitation.
 - (g) Conditions have been specified under which the distribution of annual runoff is negatively skewed
 - (h) Report in preparation.

(7473)

HYDRAULICS OF SEWER JUNCTIONS.

- (c) Prof. H. J. Leutheusser.
- (d) Experimental, basic research for master's thesis.
- (e) Sewer junctions have been found to be hydraulically inefficient. Aim is to identify deficiencies and to improve design procedures.
- (f) Suspended.
- (g) Satisfactory operation of sewer junctions calls for spatial separation of their two functions, viz., flow re-direction and confluence.
- (h) "Hydraulics of Sewer Junctions." P. Gharghour, M. Eng. Project Report, Univ. of Toronto, 1970.

(7474)

ZERO-FLOW WATERHAMMER.

- (c) Prof. H. J. Leutheusser.
- (d) Analytical and experimental; basic research for doctoral thesis.
- (e) Subject matter of inquiry: elastic wave phenomena in stagnant fluids created by motions of the flow boundary.
- (g) Solution for wave propagation in parallel laminar flow in a rectangular channel due to an arbitrary velocity input has been obtained.
- (h) "Zero-Flow Waterhammer." D. A. P. Jayasinghe, M.A.Sc. thesis, Univ. of Toronto, 1969.

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UNIVERSITY OF WATERLOO, Department of Chemical Engineering, Waterloo, Ontario, CANADA. Dr. D. R. Spink, Acting Department Chairman.

(6953)

LIQUID MIXING IN AGITATED VESSELS.

- (b) National Research Council of Canada.
- (c) Professor M. Moo-Young.
- (d) Experimental research.
- (e) The quality of liquid mixing in mechanically-agitated tanks and bubble columns is being examined in terms of energy consumption and system variables to yield design criteria for chemical and fermentation reactors.
- (g) Results to be available in publications.
- (h) Reports submitted for publication in Can. J. Chem. Eng.

(6954)

BUBBLE MOTION AND MASS-TRANSFER.

- (b) Department of University Affairs (Ontario).
- (c) Professor M. Moo-Young.
- (d) Theoretical and experimental research.
- (e) The physical and mass-transfer properties of bubble swarms are being studied for use in the design of flotation cells and aerobic waste treatment facilities.
- (g) Interim results reported in publications below.
- (h) "Bubble Drag and Mass-Transfer in Non-Newtonian Fluids." Hirose and Moo-Young, Can. J. Chem. Eng., 47, 265, 1969.
- "Generalized Expressions for Gas Absorption Rates in Bubbles." Idem, Chem. Eng. Sci.; in press.

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UNIVERSITY OF WATERLOO, Department of Civil Engineering, Water Research Laboratory, Waterloo, Ontario, CANADA. Professor T. E. Unny.

(7099)

RESEARCH IN FLUVIAL HYDRAULICS.

- (c) Professor H. M. Hill.
- (d) Basic research; Ph.D. thesis.
- (e) Investigations on the criteria for the establishment of different bed forms in movable bed hydraulics

and determination of bed roughness associated with each bed form.

- (h) "Instability of Flat Bed in Alluvial Channels." Harry M. Hill, Vajapeyam S. Srinivasan and Tharakkal E. Unny., Proc. ASCE, J. Hydraulics Div., Sept. 1969. Other publications expected.

(7100)

CONTAINMENT OF MINE TAILINGS.

- (c) Prof. H. M. Hill.
- (d) Applied research; Ph.D. thesis.
- (e) Studies on the optimization for efficient hydraulic construction of tailings dams and investigation of the techniques for the containment of mine tailings.

(7101)

INVESTIGATIONS ON SITE LOCATIONS FOR SANITARY LANDFILLS FROM POLLUTION ABATEMENT CONSIDERATIONS.

- (c) Prof. H. M. Hill.
- (d) Applied research.
- (e) Research in connection with estimation of pollutants originating in sanitary landfills.

(7102)

RESISTANCE TO FLOW WITH FLEXIBLE ROUGHNESS.

- (c) Professor Nicholas Kouwen.
- (d) Basic and applied research; Ph.D. thesis.
- (e) Fundamental studies on resistance to open channel flow with flexible roughness elements and its comparison with flow retardance in vegetated channels.
- (h) "Flow Retardance in Vegetated Channels." Nicholas Kouwen, T. E. Unny and H. M. Hill, Proc. ASCE, J. Irrig. and Drainage Div., June, 1969.

(7103)

DYNAMIC PRESSURE FLUCTUATIONS IN AN ATTACHED EDDY.

- (c) Professor Dave Weaver.
- (d) Basic research.
- (e) The pressure fluctuations in the attached eddy at abrupt changes in the channel boundaries with and without oscillations of the boundary (which is elastically supported) are being studied analytically and experimentally.

(7104)

DEVELOPMENT OF FINITE ELEMENT METHOD FOR THE SOLUTION OF FLUID DYNAMIC PROBLEMS.

- (d) Basic research; Ph.D. thesis.
- (e) Development of finite element method for computer solution of thermal convective flows described by the continuity momentum and energy equations.
- (g) Results expected to be published soon.

(7105)

DYNAMICS OF DISCONTINUOUS FLOW IN OPEN CHANNELS.

- (d) Basic research; M.A.Sc. thesis.
- (e) Dynamical pressure fluctuations on control gates subjected to the action of partly submerged hydraulic jumps have been investigated.
- (f) Research completed.
- (h) "Pressure Fluctuations on Submerged Sluice Gate." Gordon Keir, T. E. Unny and H. M. Hill, Proc. ASCE, J. Hydraulics Div., Nov. 1969.

(7106)

FLOW DEVELOPMENT IN STRATIFIED FLOWS.

- (d) Basic work; Ph.D. thesis.
- (e) Investigations on the mechanism of mixing of fluids between layers of stratified flows.

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(6959)

MODEL STUDY OF POWERPLANT INTAKE AND INTAKE GATES FOR W.A.C. BENNETT DAM (FORMERLY PORTAGE MOUNTAIN DAM), PEACE RIVER, B. C.

- (b) International Power and Engineering Consultants Ltd., for British Columbia Hydro and Power Authority.
- (d) Experimental for design and operation.
- (e) Further studies relating to the 600-foot high Portage Mountain Dam (now completed and officially named the W.A.C. Bennett Dam) on the Peace River in northern B. C., were conducted on a 1:32.2 scale model of the power plant and intake gates. Purposes of the study were (1) to study the behaviour of the emergency gate tower when operated as a surge tank; (2) to examine pressures at various points in the intake and gate structures under normal operating conditions; (3) to determine the effect of eliminating the downstream emergency gate slots, on pressures within the intake structure, particularly downstream from the gate section; (4) to check the performance of the emergency gate during the penstock filling process, and, on tests which followed intensive modification of the model, the purposes were to determine downpull forces on the service and operating gates under conditions of emergency closure, and to examine flow behaviour at, and downstream from, the gates, under normal and emergency operation.
- (f) Completed.
- (h) Report issued to client.

(6960)

MODEL STUDIES NORTH COFFERDAM STAGE 1 EXTENSION, KETTLE DAM PROJECT.

- (b) Crippen Acres Ltd., for Manitoba Hydro.
- (d) Experimental for design and operation.
- (e) Model studies of the Kettle Dam, which is part of the Nelson River Project in northern Manitoba, were continued using a 1:120 scale model to determine the size and extent of riprap protection required along the Stage 1 Cofferdam Extension and along the north river bank at the diversion channel for diversion flows up to 180,000 cfs, and to ascertain the optimum position and alignment of the rock groin and rock spurs used to protect the cofferdam during placement of the seal blanket. Flow patterns, erosion patterns and flow velocities in the diversion channel were recorded during the model studies.
- (f) Completed.
- (h) Report issued to client.

(6961)

MODEL STUDIES OF RIVER CLOSURE, KETTLE PROJECT, NELSON RIVER DEVELOPMENT.

- (b) Crippen Acres Ltd., for Manitoba Hydro.
- (d) Experimental for design and operation.
- (e) Tests were conducted on the existing 1:120 scale model of the Nelson River at Kettle Dam site to determine the most desirable procedure of placing rock dykes across the river channel to divert flow from the river channel through the intakes for powerhouse Units 8 through 12, and to ascertain sizes of material likely to be needed in the dykes to satisfactorily accomplish closure at discharges up to 180,000 cfs.
- (f) Completed.
- (h) Report issued to client.

(6962)

MODEL STUDIES OF MICA DAM FLOW CURRENTS UPSTREAM FROM DIVERSION TUNNEL INTAKES AND THEIR RELATION TO DEBRIS CONTROL.

- (b) Casco Consultants Ltd., for British Columbia Hydro and Power Authority.
- (d) Experimental for design and operation.
- (e) Studies were conducted on the existing 1:80 scale model of 600-foot high Mica Dam on the Columbia River, British Columbia, to assess the likelihood of the diversion tunnel intakes becoming clogged with floating debris; to ascertain the order of magnitude of backwater caused by clogging; to determine whether or not eddy currents upstream from the cofferdam would be conducive to retrieval of floating debris; to evaluate the effects of placing spoil material in the river opposite the intakes; to determine the limits of the spoil area to give optimum flow currents for debris retrieval and disposal operations; and to illustrate the best location for debris retrieval and disposal operations; and to illustrate the best location for debris retention log boom.
- (f) Completed.
- (h) Report issued to client.

(6963)

MODEL STUDIES OF HARBOUR PROTECTION, FISHERIES RESEARCH STATION, SANDY COVE, WEST VANCOUVER, BRITISH COLUMBIA.

- (b) Department of Public Works, Canada, for Fisheries Research Board.
- (d) Experimental for design and operation.
- (e) Tests were conducted on a 1:84 scale model of a preliminary design of a breakwater proposed for protection of wharfage at Sandy Cove, West Vancouver, British Columbia. Particular attention was to be given to the extent of wave attenuation in the harbour or dock area formed by a concrete crib breakwater, 360 feet long. The harbour, which is exposed to 4-foot to 6-foot storm waves generated by winds from the south-east then to south-west was also to be examined with respect to wave surges within the enclosed berthing area, and the action of the south-southwest waves was to be studied to ascertain the height of crib deck wall necessary to prevent overtopping.
- (f) Completed.
- (h) Report issued to client.

(6964)

CAPACITY AND HEAD LOSSES FOR FIRE HYDRANTS.

- (b) Terminal City Iron Works, Vancouver, B. C.
- (d) Experimental for design and operation.
- (e) The purpose of the hydraulic laboratory tests was to determine the capacity of various fire hydrants, to evaluate the head losses for their major component parts known as the boot and barrel, and to ascertain whether or not improvement in design could be realized.
- (f) Completed.
- (h) Report issued to client.

(6965)

MODEL STUDIES OF HYDRAULIC FORCES ON SPILLWAY STOP LOGS - SKINS LAKE SPILLWAY.

- (b) Aluminum Company of Canada Ltd., Kitimat, B. C.
- (d) Experimental for design and operation.
- (e) The 1:36 scale model represented the two gate sections of the spillway of the dam at Skins Lake, near Kitimat, B. C. Purpose of the hydraulic model studies was to determine the hydraulic downpull forces and lateral pressures on the 18-foot log gate and the three 6-foot stop logs for emergency closure conditions with various radial gate openings.

- (f) Completed.
- (h) Report issued to client.

(6966)

- HYDRAULIC MODEL STUDIES OF THE SIRIKIT DAM SPILLWAY.
- (b) Engineering Consultants Incorporated for Ministry of National Development, Kingdom of Thailand.
 - (d) Experimental for design and operation.
 - (e) Studies are being carried out on a 1:36 scale model to evaluate the hydraulic characteristics of all components of the spillway tunnels, including aeration requirements and vibration potential at critical locations in the tunnel, mean and transient pressures at selected locations, and capacity curves for free and gate controlled flows.
 - (h) Report to be issued to client.

(6967)

- MODEL STUDIES OF WAVE ACTION INDUCED BY SLIDES INTO MICA DAM RESERVOIR.
- (b) Casco Consultants for British Columbia Hydro and Power Authority.
 - (d) Experimental for design and operation.
 - (e) Extensive studies of the nature and magnitude of waves generated by landslides into a dam reservoir were conducted on a large outdoor 1:300 scale model of the reservoir formed by the 600-foot high Mica Dam presently under construction on the Columbia River in British Columbia. A section of Mica Dam was reproduced to a scale of 1:64 and data acquired from tests conducted on the 1:300 scale model of the reservoir were used as a basis for studies of the effects of waves on the dam.
 - (h) Report to be issued to client.

UNIVERSITY OF WINDSOR, Department of Mechanical Engineering, Windsor, Ontario, CANADA. Dr. K. Sridhar, Chairman, Graduate Studies, Dept. of Mechanical Engrg.

(6455)

- EFFECTS OF AN INITIAL GAP ON THE FLOW IN A WALL JET.
- (b) Defence Research Board of Canada; National Research Council of Canada.
 - (d) Experimental; basic research for M.A. Sc.
 - (e) Aim is to study the effects of an initial gap on the turbulent jet flow over plane and curved walls. A gap is introduced between the nozzle lip and the leading edge of the wall. The jet flow over the wall is probed.
 - (f) Completed.
 - (g) Region close to the leading edge of the wall could be described as a settling region where the type of flow changes from a free jet to a wall jet. In the case of curved wall jets there is an hysteresis phenomenon associated with initial gap and the angular position of the jet separation decreased with increase of the gap size.
 - (h) "Effects of an Initial Gap on the Turbulent Jet Flow Over a Curved Wall," S. C. Paranjpe and K. Sridhar, Aeronautical Jour., Vol. 72, Jan. 1968, p. 63. M.A.Sc. theses have been submitted to the Dept. of Mechanical Engrg., Univ. of Windsor.

(6456)

- EFFECTS OF CURVATURE ON JET ENTRAINMENT AND HEAT TRANSFER.
- (b) National Research Council of Canada.
 - (d) Experimental, theoretical; basic research for M.A.Sc. and Ph.D.
 - (e) Aim is to investigate the effects of the wall curvature on the jet entrainment and heat trans-

fer. The jet flow over walls of different radius and at different temperature is probed to get the velocity and temperature profiles. Correlations will be obtained.

- (h) "Experimental Investigation of Curvature Effect on Turbulent Wall Jets," K. Sridhar and P. K. C. Tu, Aeronautical J., Royal Aero. Soc., Vol. 73, pp. 977-981, Nov. 1969.
- "Turbulent Jet Flow Over a Heated Isothermal Plane Wall," S. Y. Hu and K. Sridhar, Trans. E. I. C., E. I. C. -70-Mech 1 Vol. 13, No. B1, Jan. 1970.
- (6457)
- JET FLOW OVER A MOVING WALL.
- (b) National Research Council of Canada.
- (d) Experimental; basic research for M.A. Sc.
- (e) Object is to study the effects of rotating a cylinder on the flow of a jet over it, especially the effects on the velocity profile, jet growth and angular position of separation.
- (f) Completed.
- (h) "Effects of Rotation on a Turbulent Jet Flow Over a Cylinder," H. Keil and K. Sridhar, Aeronautical J., Vol. 74, May 1970, pp. 407-410.

(6459)

- BOILING HEAT TRANSFER FROM A ROTATING CYLINDER.
- (b) National Research Council of Canada.
 - (c) Dr. T. W. McDonald.
 - (d) Experimental; applied research for doctoral thesis.
 - (e) The purpose is to investigate the effect of rotational speed of the cylindrical heater element on the boiling heat transfer coefficient. If the increase in the coefficient is significant, then heat exchangers having rotating elements may be feasible in cases where weight or size are important factors. A previous worker on this project used water as the fluid while the present worker is using "Freon." High speed photography is being used to study the bubble formation.
 - (g) A cylindrical horizontal heating element was rotated about its axis at speeds of 0-800 rpm. A maximum increase in the rate of heat transfer of approximately 100% was found to occur at a rotational Reynolds number of 14,500. For rotational Reynolds numbers greater than this value, the rate of heat transfer was decreased to values less than those occurring at very low speeds of rotation.
 - (h) "Nucleate Boiling Heat Transfer from a Rotating Horizontal Cylinder to Saturated Water," Todd McLean, Master's thesis, Univ. of Windsor Library.

(6955)

- THREE-DIMENSIONAL CURVED WALL JETS.
- (b) National Research Council of Canada.
 - (d) Experimental, theoretical, basic research for M.A. Sc. and Ph.D.
 - (e) Aim is to study three-dimensional effects on jet growth and separation.

(6956)

- DEVELOPING FLOW IN AN ANNULUS.
- (b) National Research Council of Canada.
 - (d) Experimental, theoretical, basic research for M.A. Sc. and Ph.D.
 - (e) Aim is to investigate the annular flow development for different Reynolds numbers, entrance geometry and turbulence conditions, and diameter ratios.
 - (h) "Settling Length for Turbulent Flow of Air in Smooth Annuli With Square-Edged or Bellmouth Entrances," K. Sridhar, A. A. Nicol, and A. V. A. Padmanabha, ASME Paper No. 69-WA/APH 24; also Trans. ASME, J. Appl. Mech., Vol. 37E, Mar. 1970,

(6957)

TURBULENT CYLINDRICAL BOUNDARY LAYERS.

- (b) National Research Council of Canada.
- (d) Experimental, basic research for M. A. Sc.
- (e) Object is to investigate transverse curvature effects on turbulent boundary layers.
- (f) Completed.
- (h) "Power Law for Turbulent Cylindrical Boundary Layers." Accepted for publication by Aeronautical J., Roy. Aero. Soc.

(6958)

FLUIDIC AMPLIFIERS.

- (b) National Research Council of Canada.
- (c) Prof. W. G. Colborne, Prof. H. J. Tucker.
- (d) Experimental, basic research for M. A. Sc.
- (e) Aim is to study the response time and mechanism of fluidic bistable amplifier and turbulence amplifier.

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